NRGH Climate Change Vulnerability Assessment Report | Project 7871.002

Nanaimo Regional General Hospital, 1200 Dufferin Crescent, Nanaimo, BC

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Executive Summary

A climate change vulnerability assessment was conducted for Nanaimo Regional General Hospital (NRGH) using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol version PG- 10.1. The protocol was devised to assess infrastructure vulnerability to changing climate parameters. This work consisted of identifying the potentially vulnerable infrastructure systems, determining possible climate change induced effects on relevant climatic parameters, and developing a risk rating for each possible interaction. The assessment does not evaluate the risks posed by the current climate or extreme weather events but instead focuses on the new vulnerabilities caused by climate change, as projected from climate models out to the year 2050.

The hospital infrastructure was divided according to established engineering disciplines and then further sub-divided into respective systems and sub-systems. This permitted a more refined evaluation of the possible climate interactions with the respective sub-systems. The interconnectedness and multiple vintages of hospital infrastructure systems was best approached by using a worst-case scenario analysis. As such, the most vulnerable systems define the campus-wide risk. Subsequent adaptation measures will define the required level and extent of renewal of these vulnerable systems.

Risk Assessment

The climate parameters were obtained through iterative discussions with the Pacific Climate Impacts Consortium (PCIC). The scores for probability of occurrence were provided by PCIC from a combination of professional judgment and statistical evaluation of climate model projections. The probability of occurrence score (ranging from 0, negligible, to 7, highly probable) refers to the likelihood of the climate parameter surpassing the designed climate thresholds for the hospital infrastructure systems, thus eliciting a risk of failure.

Severity scores (ranging from 0, negligible, to 7, catastrophic) were established by consensus in a facilitated workshop with all vested parties of Island Health. The severity scores are based on the anticipated impacts of system failure on the operations of the hospital.

The product of the probability and severity scores yielded the risk for the specific interactions (ranging from 0 to 49). The risks were tallied for all possible interactions and analyzed for patterns of vulnerability. Through discussions with Island Health, risk scores greater than 30 were identified as ‘high-risk’.

For each of the medium and high-risk interactions, recommendations for climate adaptation were provided. Recommendations from the PIEVC protocol were further cross-referenced with VFA Inc.’s Asset Detail Report (2012). Systems that are due for short- to medium-term replacement were prioritized to avoid lost opportunities by aligning renewal planning with climate mitigation and adaptation. Failure to coincide required renewals with changing climate loads will likely lead to additional upgrades during the system’s renewed service life, resulting in increased costs and disruption.

Vulnerable Systems and Recommendations

The assessment identified Mechanical Cooling, Mechanical Critical Air Systems, and Domestic Water Supplies as the most vulnerable to climate change. The root-cause issues for Mechanical Cooling and Mechanical Critical Air both relate to the increased sensible and latent heat loads on the cooling system. This will likely render the system unable to meet the cooling setpoints serviced by the cooling system. The Critical Air Systems are also challenged by air pollutants, mainly induced by local forest fire particulate loads. Water shortages were also identified, but direct management of the City of Nanaimo reservoir levels falls outside the jurisdiction of Island Health. Recommendations on mitigating water shortages are provided.

The high-risk interactions identified for short-term replacement are shown in Table 1.

TABLE 1 HIGH RISK SYSTEM SUMMARY

System	Component	Risk Score	Recommendation
Mechanical Cooling	Back-up Cooling Water	42	It is recommended that the cooling system study currently underway be expanded in scope to include a review of the potential impact of climate change, including the potential ability to handle climatic increases through lowering of chilled water supply temperatures.
	Cooling Towers	36	
	Chilled Water Pumps & Distribution	35	
	Chillers	35	
Mechanical Critical Air Systems	Fans	42	It is recommended to have an engineering feasibility study undertaken to determine the costs of incorporating full air recirculation for critical air systems. The study should also take into consideration operable windows and air infiltration. For systems that do not have electrostatic filtration, filtration systems should be upgraded to accommodate this feature.
	Cooling Coils	35	
Domestic Water Supply	Drinking Water Supply	35	Consider an accelerated plumbing fixture replacement program to reduce potable water consumption and strain on regional domestic water supply.
	Plumbing Fixture Supply	35	
	RO Water	35	Reduce potable water consumption for non-potable uses and/or ensure that critical potable water uses have priority in water shortage events.

A full project summary is included in Appendix A: Infrastructure Risk and Recommendations. This summary includes a description of each infrastructure sub-system; a description of the interactions with each climate parameter, the probability, severity, and risk scores associated with that interaction, and recommendations for each infrastructure system for each system with a medium to high risk score.

Glossary and Abbreviations

Adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
Adaptive Capacity	The IPCC defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate damages, to take advantage of opportunities, or to cope with the consequences.
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
Boundary Condition	The set of conditions that establish the limits of the scope of the assessment. Boundary conditions include definition of the time horizon, geographic boundaries, jurisdictional authority, and features of the infrastructure that are within the mandate of the vulnerability assessment.
Climate	Defined as the statistical description of weather over a period of time ranging from months to thousands of years.
Climate Event	A climatic condition that the infrastructure could experience deemed relevant for consideration in the vulnerability assessment.
Climate Indicator	A term used to describe the direct outputs of a climate change simulation model (GCM or RCM). Derived model outputs are described as secondary climate indicators.
Climate Model	A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties.
Climate Parameter	A specific set of weather conditions or climate trends deemed to be relevant to the infrastructure under consideration.
Climate Prediction	An estimate of future climate quantities (means, statistics) over a defined time horizon.
Climate Projection	An estimate of longer-term future climate.
DDC	Direct Digital Control
Design Life	The period of time during which the infrastructure is expected to operate within design parameters. Notionally, the length of time between commissioning and the onset of wear-out. Typically, design life is a shorter duration than the period between commissioning and the anticipated time of actual failure. In some cases, design life is stated in terms of the economic return period of an engineering project. The design life of the infrastructure as a whole may be different than the individual components that comprise the infrastructure based on routine refurbishment or replacement of components over the useful life of the infrastructure.
DX	Direct Expansion
Engineering Analysis	Establishing the relationship between remaining useful service life, performance demands and other relevant factors of the infrastructure and changing-climate impacts, in order to

	calculate a numeric representation of Vulnerability, Adaptive Capacity and Infrastructure Resiliency.
Global Climate Model (GCM)	Complex computer programs commonly used to simulate the atmosphere or ocean of the earth and project climate trends on a global scale. The mathematical models are based on general circulation of the planetary atmosphere and apply thermodynamics to calculate radiation and latent heat in order to establish a global mass and energy balance.
HVAC	Heating Ventilation & Air Conditioning
Infrastructure Component	One of a number of physical features, processes, procedures and/or human resources that comprise the infrastructure.
Infrastructure Response	The generally anticipated effects arising from the climate and other change parameters interacting with the infrastructure components.
Infrastructure Threshold Value	A value representing an infrastructure specific weather event or climate trend that triggers an undesirable infrastructure response.
Interaction	The interface between weather events and/or climate trends and infrastructure components.
IPCC	Intergovernmental Panel on Climate Change
LED	Light Emitting Diode
MDR	Medical Device Reprocessing
NICU	Neonatal Intensive Care Unit
OR	Operating Room
PAR	Post-anesthesia Recovery
Probability Score Factor	A factor based on an arbitrary score (0 to 7) used to define the probability of a weather event or climate trend impacting a particular infrastructure component.
Professional Judgment	The application of training, knowledge, experience, and skills gained over a prolonged period of professional practice.
Risk (R)	The possibility of injury, loss or negative environmental impact created by a hazard
Regional Climate Model (RCM)	Regional climate models (RCMs) provide climate projections on a smaller grid scale than GCMs. They are based on GCMs to initiate the model process then produce parameters on the smaller scale using a process called dynamic downscaling.
Representative Concentration Pathway (RCP)	Greenhouse gas concentration trajectories adopted by the IPCC for the fifth Assessment Report.
Resiliency	The ability of an infrastructure, or infrastructure component, to absorb a projected weather event or climate condition and still maintain a level of service within design or operational tolerances.
Risk Tolerance Threshold	The risk score values established by the infrastructure owner that define high, medium, low and special-case risk scores.
Robustness	In terms of climate projections, robustness defines the level of variability or uncertainty of model results.

Secondary Climate Indicator	Derived model outputs from multiple climate indicators (e.g. mean coincident wet-bulb).
Severity Score Factor	A factor based on an arbitrary score (0 to 7) used to define the severity of the consequences of a weather event or climate trend impacting a particular infrastructure component.
Useful Service Life	The time between commissioning an infrastructure, or infrastructure component, and mandatory refurbishment or replacement.
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of changing climate, including climate variability and extremes.
Weather	The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity, and barometric pressure.
Weather Event	Specific atmospheric conditions related to temperature, moisture, wind velocity, and barometric pressure.

1 Introduction

1.1 Project Objective and Scope

The overall objective of the Nanaimo Regional General Hospital Climate Change Vulnerability Assessment (Assessment) is to assess infrastructure components of the Nanaimo Regional General Hospital (NRGH) that are at risk of failure or impaired service function due to extreme climate events or a change in climate normals. Building codes have traditionally been based on historical climate data for specific regions. Buildings and infrastructure have also been designed with specific climate loads based on historical climate data. As climate changes, there is a potential for infrastructure to be subject to climate conditions and loads that it was not designed for. It is important, therefore, to account for future climate conditions when assessing building resiliency, maintenance, and future renewals, retrofits, and additions.

Risk is defined as a function of the probability of an event occurring and the severity of its consequence. Several objectives were pursued to determine risk:

- → Identify building infrastructure components affected.
- → Identify key climate parameters that could affect NRGH building infrastructure.
- → Perform an assessment of the probability of occurrence of climate events.
- → Perform an assessment of the severity of consequences for interactions between climate events and the utility and function of infrastructure components.
- → Perform an engineering analysis on interactions deemed at risk.

The scope of this project encompasses the current design, construction, operation, maintenance and management of the NRGH campus infrastructure. The Assessment addresses potential impacts of current and future climate to the year 2050.

1.2 PIEVC Protocol

PIEVC is an acronym for the Public Infrastructure Engineering Vulnerability Committee. The PIEVC Engineering Protocol for Infrastructure Assessment and Adaptation to a Changing Climate (Protocol) was developed by Engineers Canada to assess the vulnerabilities of public infrastructure to the impacts of changing climate. The Protocol analyzes both infrastructure and climate information and evaluates potential interactions between them. Information gathered through the Protocol process is intended to assist owners and operators make informed decisions about infrastructure operation, maintenance, planning and development. PIEVC version PG – 10.1 (June 2016) was used for this work.

The methodology of the Protocol includes five key steps to ensure the assessment is consistent and rigorous. The five key steps are:

1. Project Definition
2. Data Gathering and Sufficiency
3. Risk Assessment
4. Engineering Analysis (optional as necessity and resources permit)
5. Recommendations and Conclusions

The Assessment follows these key steps and this report is generally organized accordingly.

1.3 Project Team

The NRGH climate change vulnerability analysis project was a team effort among the consulting team, Island Health, and the Project Advisory Committee. The consultant team members and roles are listed below in Table 1.1. The full list of participants and their roles are included in Appendix F: Project Team Members.

TABLE 1.1 – PROJECT CONSULTANT MEMBERS AND ROLE		
Project Manager	Harvey Goodman, P.Eng.	RDH Building Science Inc.
Project Manager	Robert Lepage, MASc., P.Eng.	RDH Building Science Inc.
Mechanical System Lead	Douglas Spratt, MSc, P.Eng.	Prism Engineering Ltd
Electrical System Lead	Casey Gaetz, LC	Prism Engineering Ltd.
Structural System Lead	Robert Lepage, MASc, P.Eng.	RDH Building Science Inc.
Enclosure System Lead	Robert Lepage, MASc, P.Eng.	RDH Building Science Inc.
Water System Lead	Christy Love, P.Eng.	RDH Building Science Inc.
Civil System Lead	Darryl Tunnicliffe, P.Eng.	McElhanney Consulting Services Ltd.
PIEVC Advisor	Greg Allen, BASc., P.Eng.	Rivercourt Engineering
Climate Change Advisor	Deborah Harford	Simon Fraser University

2 Project Definition

The PIEVC Protocol was created to assess the climate risks and vulnerabilities associated with public infrastructure at a screening level. To limit the scope to only include items that fall under the jurisdiction of the representing authority, careful consideration of ownership delineation is required. While NRGH relies on off-site services that fall outside of Island Health's jurisdiction, these services were not subjected to the PIEVC protocol but were nonetheless analysed in Sections 2.3 and 4.3. The focus of this assessment lies within those systems and services that fall within the jurisdictional limits of Island Health.

The protocol was not applied to future infrastructure developments at NRGH. There are too many unknowns associated with actual performance and potential variation from proposed designs, to yield practical or useful recommendations. Consequently, planned and upcoming infrastructure elements were not considered within the scope of this assessment.

2.1 Nanaimo Regional General Hospital Campus

NRGH is an acute care hospital facility providing a wide range of healthcare services including surgical, psychiatric, intensive care, rehabilitation, and other clinical services such as laboratory, medical imaging and educational services. It is the second largest hospital campus on Vancouver Island, serving approximately 350,000 people. The hospital campus has a gross floor area of 54,441 m^2 (585,999 sq. ft.). The original building's nursing tower was constructed in 1963, and various buildings have been added from 1969 to 2012 to expand services. The following additions were completed at the hospital in addition to various renovations throughout the years:

- → Rehabilitation and food services wing, 1969
- → Major "Phase 1" addition, 1992
- → Ambulatory care addition, 1995
- → Renal and perinatal unit addition, 2008
- → New emergency department, 2012

The buildings at NRGH are typically of steel and concrete construction with varying building envelope assemblies depending on time of construction.

Figure 2-1 – Aerial View of NRGH

The hospital is approximately 85m above sea-level and situated on an east-facing slope west of the downtown core of the City of Nanaimo. It is connected to the rest of Vancouver Island to the west by the Nanaimo Parkway– Highway 19, and to the east by the Old Island Highway 19A. It is identified by the Köppen climate classification system as a cool-summer Mediterranean zone, and by the Department of Energy (US) as Climate Zone 4/5. Nanaimo winters have been mild and rainy, while the Vancouver Island Mountain Range's effect on Pacific weather systems have resulted in typically dry summers. Future climate projections suggest that the Nanaimo region will warm by around 3°C on average and be associated with roughly a doubling of the number of days above 25°C. Precipitation is projected to decrease in the summer and increase in all other seasons, with an almost 25% increase on average for the 1 in 20-year one-day precipitation event.

2.2 Hospital Infrastructure

Hospitals have exigent operational requirements to provide medical service functions. This requires specialization in multiple fields to ensure properly designed and operating infrastructure. The assessment process was streamlined by dividing the infrastructure into sectors based on traditional engineering disciplines: Mechanical, Electrical, Structural, Enclosure, Water, and Civil engineering. Each discipline was further divided into its respective systems, sub-systems, and sub-system components. The term *Infrastructure Components* may reference any material aspects of the building, from systems to sub-system components. The hospital infrastructure hierarchy used within this report is shown in Figure 2-2.

This breakdown does not include the interdependencies between different systems, as the intent is to isolate each infrastructure component to identify any potential interactions with climate change parameters. Inherently, any vulnerabilities to the dependent systems would be captured by the risk assessment in the supplying systems.

For a complete list of infrastructure components, refer to Appendix E: Summary of Infrastructure Components.

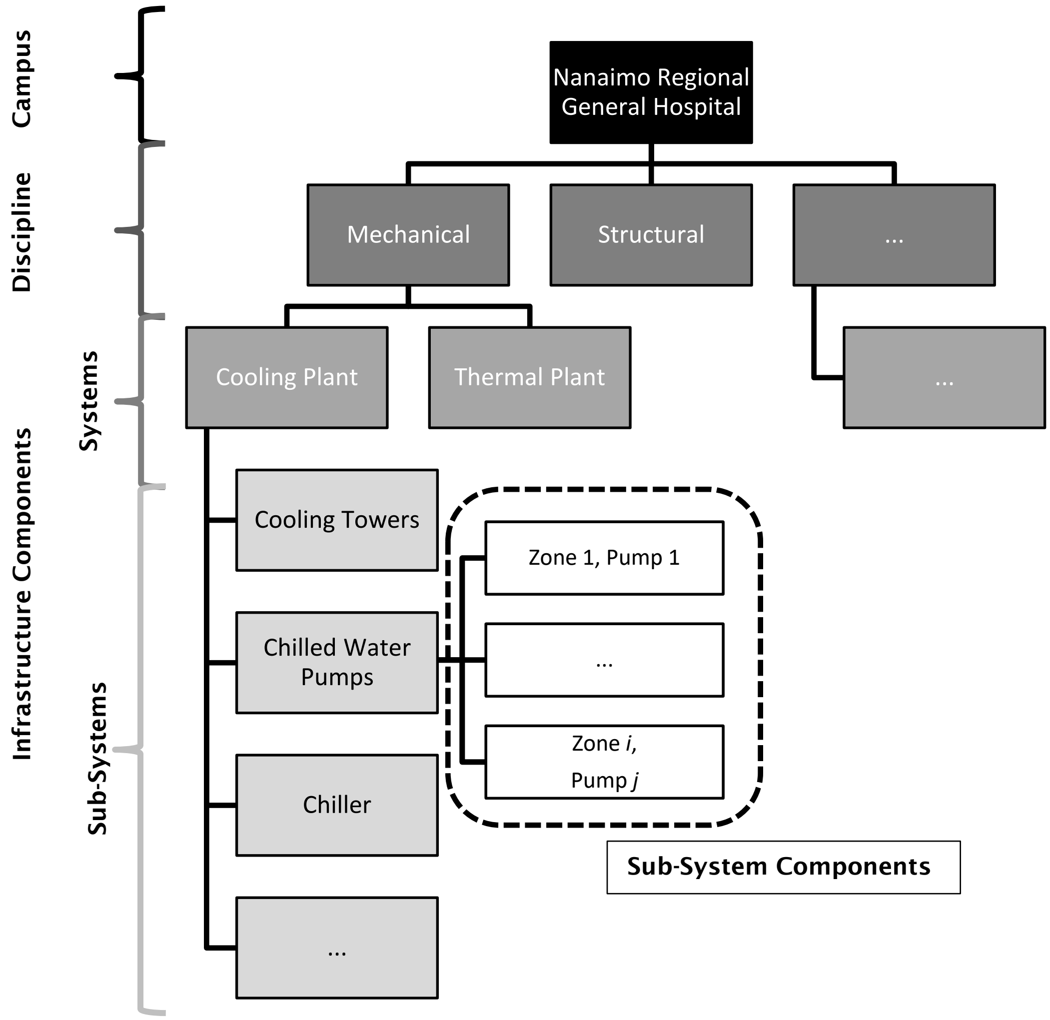

Figure 2-2 – Hospital Infrastructure Mechanical Component Hierarchy

Due to the complexity of the hospital system, the risk assessment can only reasonably be made on the sub-system level. Sub-system components may experience vastly different exposures and conditions and the complexity of analysing each sub-system component is beyond the scope of this high-level assessment. Furthermore, the interconnectedness and multiple vintages of hospital infrastructure systems necessitated an evaluation approach that could identify systemic vulnerabilities for further assessment. Instead of conducting vulnerability assessments for each separate wing, possibly duplicating work and encountering challenges in district and shared infrastructure (e.g. district heating), a worst-case, campus-wide analysis was used. This does not necessarily identify all sub-components within the system as being vulnerable, but rather that a vulnerability exists within the system. Building upon this identified vulnerability, a review of the system prior to incorporating the adaptation measures will identify which sub-component(s) need remediation.

2.2.1 Mechanical

Cooling Plant

Cooling medium is produced by the following chiller plants:

1. A nominal 405-ton Multistack chiller (model msisxcic2h2aa), located in Phase 1, serving phases 1 and 2, using refrigerant R410A
2. A nominal 500-ton Trane chiller (model cvhf049fa4x0pe), located in Phase 1, serving phases 1 and 2, using refrigerant R123
3. A 20-ton Airstack unit (model asp020xc12), located on level 3 roof, serving MRI/CT, using refrigerant R410A
4. Another 20-ton Airstack unit (model asp020xc22), located on level 3 roof, serving MRI/CT, using refrigerant R410A
5. A 43-ton York chiller (model ycal0043ee), located on level 3 roof, serving the Kitchen, using refrigerant R410A
6. A 290-ton Climacool chiller (model uch070anasahbos), located in the ED Basement, serving ED, using refrigerant R410A
7. A 200-ton McQuay chiller (model peh063, style 9961541010), located in the West Mechanical Room, serving Rehab/Ambulatory, using refrigerant R134A

Associated cooling plant equipment includes chilled water distribution piping and circulating pumps and provides chilled water to the cooling coils of air handling units. Various plant interconnections have been installed and plans are underway for improved interconnectivity for redundancy and efficiency.

Critical Air Systems (Operating Room, Neonatal Intensive Care Unit, Post-Anaesthesia Recovery, Medical Device Reprocessing)

Most systems are 100% outdoor air, with some having electrostatic filters, but all having two stages of filtration, preheating coils, cooling coils, and supply fans. Humidification is limited to a few air systems.

Direct Digital Control (DDC) System

The DDC system includes control panels and end devices such as control dampers and control valves.

Food & Housekeeping Services

Local freezers and coolers include evaporator units and outdoor condensing units.

Medical Gasses

Medical air is produced from an indoor air compression system including filtration and drying. Air intake is at the front of the ER ward. Medical oxygen is provided by an offsite supplier with trucked-in supply stored in onsite storage tanks.

Other Central Air Systems

Non-critical central air systems typically are comprised of two-stage filtration pre-heating, heating and cooling coils, and supply fans. The main Tower air system has a cooling coil, but the supply air distribution does not extend into the patient rooms, only the corridors and discharge air temperatures are kept warm (above approx. 17˚C) to avoid condensation.

Thermal Plant

Primary heating is by steam, fed from the mechanical boiler room. There are three hot water boilers, two of which are used for winter heating and one for summer steam needs. The generated steam is piped through hot water shell and tube heat exchangers. These heat exchangers allow heating of the hot water for space and ventilation air heating. The hot water heating system consists of distribution piping, circulating pumps, and coils in the air-handling units, along with other terminal heating devices. Boilers have dual fuel (gas/oil) burners. The average steam load is approximately 20,000 lb/h with a primary (header) steam pressure of 125 psig.

Unitary HVAC Systems

Rooftop units typically have direct expansion (DX) cooling coils and integral condensers, along with filtration and some form of heating (heat pump heating, electric resistance, or hot water). Split systems typically involve indoor (ducted or ductless) evaporators and outdoor condensers or heat pump units (typically mounted on roofs).

2.2.2 Electrical

BC Hydro Supply

BC Hydro provides electrical power supply to the facility. This service is provided via overhead power lines as routed along the street edge to the utility power substation located off facility grounds. This service consists of a primary and an alternate feed, providing system redundancy and resilience.

Main Distribution Transformers

The BC Hydro supply feeds transformers that reduce the voltage as supplied to the facility at 25 kV. Voltage is reduced to 347/600 Volts which is utilized by the major mechanical and some lighting equipment for operation. Additional smaller transformers further reduce the voltage to 120/208V for most plug loads etc. The system design utilizes two main transformers. Each transformer is sized to handle 100% of the facilities' power requirement. Through the use of a tie breaker, power can be shared between the two transformers or if one should fail, one of the transformers should be able to service the full facility.

Main Medium Voltage Distribution Equipment

The primary equipment in this system includes switching mechanisms which distribute power to the secondary distribution equipment.

Low Voltage Secondary Distribution Equipment

The primary equipment in this system includes high quality electronically controlled and operated breakers.

Back Up Power

There is a back up power generation system in place consists of three diesel generators which feed essential (life safety, vital and delayed vital) loads throughout the facility. The existing generators are: one 450kW and two 750kW. In order to meet the demand requirements for the new essential power supply, the three existing generators are being replaced with three new 1.5MW generators. All essential loads throughout the facility will receive back up power from these generators in the occasion of a utility power failure.

Lighting – Interior

Lighting in the interior is provided by fluorescent lights. Some fluorescent lights are powered through the emergency distribution system.

Lighting – Exterior

The primary equipment for exterior lighting is site painted steel lighting poles and new LED luminaires.

2.2.3 Structural

The structures of the hospital are designed to be capable of withstanding physical loadings and forces without danger of collapse or loss of serviceability of the buildings. The structural systems of the hospital broadly consist of either primary or secondary structures. Primary structural elements are those that provide the support functions for the building, mainly live and dead gravity loads, but also building level lateral loads, including wind and seismic. Secondary structural elements are those that generally only need to support self-weight or nominal environmental loads (snow, rain, wind), but may also provide life-safety services, such as guard-rails and guard-walls. Infill walls are also classified as secondary structural items as they are only designed to accommodate lateral loads and do not provide load bearing roles. Loads are generally determined by the building code and/or best practices in effect at the time of building design.

Primary Superstructure

The multi-phase nature of the hospital campus has resulted in several types of superstructures. Reinforced cast-in-place concrete with infill walls form the main structure in the Main Block and Rehabilitation Block, with lateral loads transferred through exterior shear walls. The structure of the Ambulatory Care wing consists of steel framed section, with Hollow Structural Steel (HSS) diagonal bracing. The Renal and Perinatal buildings are also steel frame, but supported with internal shear walls.

Foundations generally consist of reinforced cast concrete on strip footings. Reinforced slabs-on-grade are located in several areas.

Secondary Structures

Multiple secondary structural items are found throughout the campus. Awnings and concrete overhangs provide aesthetic, shading, and water shedding services. Guard-rails and guard-walls provide life-safety to occupants, and stairs and ramps provide access to the building. Telecommunications and other accessories are mounted on secondary structural items.

2.2.4 Enclosure

The building enclosure provides the environmental separation between the interior and the exterior of the building; i.e., the control of the flow of heat, air, and moisture between the indoor and outdoor environment. While it does not govern the interior environmental conditions, it does control part of the load that the mechanical heating and cooling systems experience.

The enclosure consists of multiple sub-systems and components and includes all opaque wall assemblies, fenestration, insulation, waterproofing, enclosure penetrations, air and vapour barriers, and interior and exterior finishes.

Fenestration

The fenestration systems on the building are the transparent and operable sections of the wall assembly that permit the passage of light and may also function to permit the flow of air. Doors are commonly included within the fenestration classification, including swing and sliding glass doors. These components also function to restrict heat flow, as is the case of insulated glazing units (IGUs). Many different types and styles of fenestration are found in the different eras of the hospital. Single-glazed windows in thermally unbroken aluminum frames are common in the Nursing Tower and the Rehabilitation Wing; newer wings have curtain wall, window wall, and punch windows with IGUs.

Insulation

The insulation of the enclosure, in walls, roofs, and sub-grade systems, restrict the conductive heat flow through the enclosure and moderate the effects of the outdoors to the indoor conditions. Different types of insulation, and different levels of insulation, are found throughout the hospital. The typical insulation type found in the enclosure is batt insulation between studs, rigid foam board insulation in the Nursing Tower; while the roof is typically insulated with rigid foam board.

Waterproofing

The waterproof membranes at the hospital minimize water ingress through the walls, foundation, and roof. Waterproof membranes on the roofs having varying remaining service lives and consist of:

→ Roofing tar and felt built-up roofing membrane,

→ Two variations of SBS (styrene-butadiene-styrene) modified bitumen “torch-on” membranes: a conventional roofing assembly and a protected roof assembly. The difference between these two is the relative position of the membrane with respect to the roof insulation. Protected roof membranes are covered by insulation and ballast which helps prolong service life but at higher relative maintenance and replacement costs.

Not all of the wall systems have a waterproof membrane as some rely on mass storage (i.e. the ability to absorb, store, and permit subsequent drying of precipitation). This is observed mainly in the older hospital structures (e.g. the Nursing Tower). The newer buildings appear to use a combination of water resistive self-adhering waterproof membrane, asphalt impregnated building paper, and polyolefin waterproof membranes.

Penetrations

Penetrations are discontinuities in the enclosure to allow transfer of mass (e.g. air) or energy (e.g. electrical wiring). These discontinuities represent a weakness in the enclosure which could be more susceptible to climate events. Penetrations for supply and exhaust of the ventilation systems, electric conduits, telecommunications cables, potable water piping, and fire suppressions systems are all present throughout the campus.

Vapour and Air Barriers

Vapour barriers control the diffusion of water vapour through the enclosure. Air barriers prevent bulk air flow between the interior and exterior environment. Both affect the moisture durability of the enclosure. Air barriers are also critical in controlling indoor air quality by mitigating infiltration of unfiltered outdoor air, and also affects the coil loads on the mechanical system.

There are both intentional and unintentional vapour barriers on the campus depending on vintage of the building. Different types of air barriers have also been used. However, it appears that a combination of polyethylene sheet and exterior self-adhering membranes constitute the largest segment of air barriers. The continuity and quality of the air barriers is unknown.

Surface Finishes

The surface finishes are the aesthetic portions of the enclosure. These generally constitute the drywall paint or wallpaper on the interior, and paints, acrylic stucco finish, claddings, coverings, or liquid applied membranes on the exterior of the buildings.

2.2.5 Water

Domestic Water System

The domestic water system at NRGH is pressure fed from the City of Nanaimo. The City of Nanaimo reservoir is retained by the South Fork Dam which has approximately 17 million cubic metres of live storage. The City of Nanaimo has ample water supply for current demands. The 2007 City of Nanaimo Water Supply Strategic Plan, which included considerations for climate change, indicated that more supply may be required between 2020 and 2025. The need for additional storage is dependent on population growth and consumer user rates. According to City of Nanaimo staff, the need for additional storage will be re-assessed in the near future.

There are two main feeds to the hospital: a 200mm service at the south end (at the new water services building) and a 150mm service at the north end. The services are interconnected via a continuous loop and either service can feed any portion of the hospital.

The system dates back to the construction of the original two buildings, namely the 1960s for the Tower and the early 1970s for Rehab/Ambulatory Services. The water services building, with associated new pipes, valves, and municipal connection, was tendered in 2014 and presumed to be completed in or around 2015.

There is no dedicated non-potable water system serving the hospital, so the domestic water system serves all potable and non-potable water needs in the hospital. There is a reverse osmosis system for additional treatment for labs, renal, and medical device reprocessing. This system is on emergency power.

There is no on-site potable or non-potable water storage, nor any on-site water sources such as a well or rainwater collection. Fire hydrants on-site are connected to the water loop and can be connected via flexible 3" water lines for external backup potable water supply in an emergency situation.

Building Stormwater Management System

Building stormwater drainage is via roof drains connected to internal rainwater leaders which are gravity fed to the hospital's underground stormwater collection system.

According to the VFA reports (dated Dec 29, 2014), the age of roof drains and rainwater leaders correspond with the date of original building construction (Tower, 1967, through Emergency/Main Entrance, 2013). Some of the drains may have been replaced with the roof membrane replacement completed on the Tower in 1987, and on the Rehab building in 1993.

2.2.6 Civil

Landscaping

The hospital area was assumed to be bordered by Dufferin Crescent to the south, Boundary Crescent on the west, Nelson Street to the north, and by Dufferin Place to the west. The total hospital area is approximately 11.4 hectares, with approximately 5 hectares (44%) being vegetated or permeable areas. The landscaping consists of grasses, low shrubs, tall coniferous trees, and various ornamental trees. Impermeable surfaces are mainly pavement and walkways, including the building footprint. Infrastructure components of landscaping include retaining walls, drainage, and irrigation. Landscaping at NRGH is mainly aesthetic in nature.

Site Access System

Site Access Systems include asphalt roads and parking areas, concrete sidewalks, helipad, and loading docks. There have been various upgrades and expansions of site access throughout the lifespan of the hospital and the system is generally in good condition.

Stormwater Collection System

Stormwater outside of the building is collected via catch basins. There are a few vegetated storm swales or 'bioswales' located near the emergency hospital entrance. These swales improve surface infiltration capacity that will reduce stormwater discharge.

All storm drains discharge to the City of Nanaimo's municipal stormwater collection system.

2.3 Off-Site Infrastructure Services

Systems that extend beyond the property lines of the hospital are beyond the scope of this assessment. However, these external services are critical for the operation of the hospital. Assessing the upstream/downstream climate change vulnerability of these systems is not feasible based on the jurisdictional limitations of the risk assessment, but evaluating the importance of these systems to hospital operations can establish the limits for best and worst-case scenarios. The following critical services were identified:

- → Electricity (BC Hydro)
- → Natural Gas (Fortis BC)
- → Diesel
- → Telecommunications: Telephone, Internet
- → Potable Water (City of Nanaimo)
- → Sewer systems (City of Nanaimo)
- → Storm-sewer system (City of Nanaimo)
- → Transportation (City of Nanaimo, Province of BC)
- → Garbage Removal (City of Nanaimo)
- → Commodities (medical supplies, food, laundry)

Interruption in any of these services can have ranging effects from minor impairments to major disruptions on hospital operations, depending on the duration of the service suspension. The consequences can be mediated with the use of back-up or redundant systems, material and medical supply reserves, and with hospital emergency protocols. For the purposes of this assessment, it was assumed that these mitigating measures were not available, to ensure a worst-case scenario is described.

3 Future Climate Projections

The selected timeframe by the NRGH team for climate risk and vulnerability analysis was projected out to the year 2050. To provide conservative estimates (high-estimates) in climate projections, an Representative Concentration Pathway (RCP) of 8.5 $W{\cdot}m^{-2}$ was assumed for all climate parameters.

3.1 Climate Modelling

Climate change will result in differing environmental conditions that new and existing buildings will need to withstand. Currently, potential building code parameters with respect to climate change are not available from the BC Building Code (BCBC). The National Research Council Canada has announced future editions of the National Building Code of Canada (NBC) will be updated to reflect the effects of climate change.

Climate models are required to project future climate parameters. A climate model is a numerical tool based on mathematical equations to represent processes of the climate system. These run simulations to develop climate projections. Global climate models have a typical resolution of approximately 100-300 km, whereas regional climate models have a typical resolution of 45 km or less.

The Pacific Climate Impacts Consortium (PCIC) used simulations based on 12 different global climate models to determine future climate projections. PCIC downscaled nighttime low and daytime high temperatures and daily precipitation variables from the global climate models to a resolution of approximately 10 km with an elevation correction to 800m.

There were three limitations to these projections. First, the downscaled projections were only available for the daily temperature and precipitation but the building code and standards requires additional parameters, such as humidity and wind. Second, they were limited to daily time resolution instead of smaller timespans. Last, only the three stated climate scenarios, the RCP of 2.6, 4.5, and 8.5 $W{\cdot}m^{-2}$, could be downscaled. There were two options to address these limitations.

First, projections from the CanRCM4 regional climate model with a resolution of approximately 25 km could be used. This model was also limited to daily time resolutions and relied on a single climate model. This would provide all variables on a common resolution but at the expense of having only a single climate model, and not being able to well represent the possible range of future change under different amounts of climate sensitivity and climate variability.

The second option was to use the global climate models without downscaling to project the remaining climate variables. Two of the twelve models did not have all the climate variables available to them, therefore a smaller subset of 10 global climate models were used. These projections would still be limited to daily time-values and have a larger spatial resolution, but would have the benefit of using 10 climate models and be directly comparable with the three downscaled indicators.

The second option was chosen as it was deemed important to have a wide range of data from multiple climate models. Climate parameters were then determined based on these projections.

3.2 Climate Parameters

Climate change is mainly expressed as either slowly changing climate norms or through unusually severe and intense weather events. In a situation with no changing climate, the need to conduct a climate change assessment would be unnecessary. Extreme weather events would still occur, as they do currently, but may be affected by new climatic conditions. Within the context of this assessment, the PIEVC Protocol defines the risk based on the probability or likelihood of extreme weather events or creeping climate norms that exceed defined thresholds in which the infrastructure component experiences reduced performance, damage, or failure. The thresholds are generally defined based on historical climate data which were used to design the infrastructure systems.

The climate parameters were identified based on the relevant impacts they may have on the hospital's identified infrastructure (e.g. heat waves, storm intensity, etc). Each parameter was defined based on climate indicators that have established meaning in the design of building systems, such as climatic design values provided in building codes or standards.

There is a level of uncertainty associated with predicting how climate parameters will change in a specific location and timeframe. The climate parameters are therefore necessarily a blend of site-specific data and projections in conjunction with professional judgement. For this reason, each climate indicator has a certain level of robustness determined by the client scientist.

The PIEVC protocol provides two methods to define a probability score: Method A for qualitative assessments on the probability of occurrence, and Method B, for a quantitative, probabilistic assessment. The definitions for the scores for the respective methods are shown in Table 3.1. Some climate parameters are characterised by weather events, such as flooding, which can be defined stochastically (e.g. by their return periods), but the incremental increase in probability of occurrence caused by climate change is more difficult to assess. When suitable, Method B was generally preferred when the probability of occurrence could be defined quantitatively. For climate parameters that are not readily described stochastically, Method A was used to define the qualitative risk of occurrence.

TABLE 3.1 PIEVC PROBABILITY SCORES		
Score	**Probability**	
	Method A	**Method B**
0	Negligible Not Applicable	< 0.1%
1	Highly Unlikely Improbable	1%
2	Remotely Possible	5%
3	Possible Occasional	10%
4	Somewhat Likely Normal	20%
5	Likely Frequent	40%
6	Probably Often	70%
7	Highly Probable Approaching Certainty	>99%

Table 3.2 defines which climate parameters were chosen, the probability of occurrence, and the robustness of the results. The source of the definitions were identified through discussions with PCIC and consist of a combination of standard weather indices, published literature (PIEVC protocol, ASHRAE, BCBC, NBC), and professional engineering practice. The projection robustness ranges from low to high and represents the relative confidence in model output within the context of the defined climate parameter; robustness was qualitatively established on the professional judgment of the PCIC climate scientists. The current and predicted range of values for the 10th, 50th (i.e. average), and 90th percentile under RCP 8.5 assumptions are provided in Table 3.3. The parameters are aggregate of several measurable and quantifiable indices which are discussed in detail in Appendix B.

TABLE 3.2 CLIMATE PARAMETERS WITH PROBABILITY SCORE AND LEVEL OF ROBUSTNESS		Probability Score	Projection Robustness	Method
Climate Parameter	Definitions	0-7	H/M/L	A/B
Contaminated Water	Water quality insufficient for hospital purposes due to high particulate (turbidity) or organic materials (BOD).	1	L	A
Heat Waves	A stretch of unseasonably warm weather.	7	L to H	B
Strong Winds	Sustained and gusting wind speeds that pose a threat to public safety and property.	3	L	B
Storm Intensity and Frequency	Increase in frequency of storms, and storm intensity, in terms of daily precipitation in the 95th percentile and wind-driven rain pressures.	4-6	M	B
Warmer Winters	Heating degree days base 18.3˚C (ASHRAE) as general indicator of heating needs throughout the winter.	7	H	B
Air Pollution (Forest Fires)	Number of seasonal regional fires and local impacts experienced from lower mainland impacts.	5	L	A
Cold Snap	Cold spell duration where the daily maximum temperature is less than the 10th percentile.	0-1	H	B
Winter Storm (Ice Storm)	The rain on snow load pressure, as defined by the BCBC, and risks of freezing rains.	2	L	B
Humidity	Increased humidity, defined by the mean coincident wet bulb temperature.	7	M	B
Daily Temperature Range	Monthly mean difference between the maximum and minimum daily temperature.	3	L	A
Drier and Warmer Summers	Dry spell duration with less than 1mm of rain.	5-7	M to H	B
Water Shortages	Shortages in municipal water reservoirs. Uses monthly maximum value of daily maximum temperatures as an analogue for reservoir capacity.	6	H	A
Sea Level Rise	Approximately 1m/century.	7	H	B
Warmer Domestic Water Supply	The ground temperature 1m below grade. The average summer time temperature is used as a substitute.	6-7	M	B
Flooding	1 in 50 year 1-day rainfall and 1 in 10 year 15-minute rainfall for risks of overwhelming drainage systems.	2-4	M	A

TABLE 3.3 CLIMATE PARAMETERS – CURRENT AND PROJECTED VALUES		Code / Present Values For Nanaimo	RCP 8.5 – 2050 Projected Relative Values		
Climate Parameter	Indicator		10%	Avg	90%
Contaminated Water	Biological Oxygen Demand/ Particulate Suspension	<=5NTU, Coliform <10/100mL	-	-	-
Heat Waves	Cooling Dry Bulb (0.4%) [˚C]	26.8 [1]	28.8	30.0	31.2
Strong Winds	1/50 Wind Pressure [Pa]	500 [2]	116	505	890
Storm Intensity and Frequency	1/5 Wind Driven Rain Pressure [Pa]	200 [2]	40.9	205	378
Warmer Winters	Heating Degree-Day Base 18.0 [˚C-Day]	3000 [2]	1884	2165	2465
Air Pollution (Forest Fires)	N/A	-	-	-	-
Cold Snap	Heating Dry Bulb (1%) [˚C]	-8 [1]	-3.5	-2.3	-0.6
Winter Storm (Ice Storm)	Snow Load [kPa]	2.3 [2]	0.46	1.15	2.07
Humidity	Mean Coincident Wet Bulb [˚C]	17 [1]	18.2	19.6	20.7
Daily Temperature Range	N/A	-	-	-	-
Drier and Warmer Summers	Cooling Degree Day Base 18.3 [˚C-Day]	67 [1]	160	308	442
Water Shortages	Monthly maximum daily maximum temperature [˚C]	30.6 [3]	33	34.2	35
Sea Level Rise	N/A	-	-	-	-
Warmer Domestic Water Supply	Average summer time temperature [˚C]	30.6 [3]	32.7	34.1	35.0
Flooding	1 in 50 year 1-day rainfall [mm]	91 [2]	99.8	116	134.2

[1] From ASHRAE Climate Data 2015
[2] From BC Building Code 2012
[3] From Climate Norms

4 Risk Assessment

4.1 Methodology

Risk assessment is the process of identifying hazards, the severity created by those hazards, and the probability of occurrence. The PIEVC protocol defines risk as:

> *The possibility of injury, damage, loss, loss of function, or negative environmental impact created by a hazard. The significance of risk is a function of the probability of an unwanted incident and the severity of its consequence.*

Functionally, risk is defined as the product of the probability of the hazard occurring and the severity created by that hazard on hospital infrastructure and operations should the hazard occur. The probability of a hazard occurring and the severity of its occurrence are independent.

$$Risk = Probability \times Severity$$

The probabilities of the climate parameters occurring were obtained from PCIC and described in Section 3. The severity score is rated by comparing the forecasted conditions to the infrastructure's designed threshold for safe operations. The definition of two methods of severity scoring is provided in the PIEVC protocol, and reproduced in Table 4.1 below. Method E, the loss of serviceability, capacity, and function, was used.

TABLE 4.1 PIEVC SEVERITY SCORES

Score	Severity	
	Method D	**Method E**
0	No Effect	Negligible Not Applicable
1	Measurable	Very Low Some Measurable Change
2	Minor	Low Slight Loss of Serviceability
3	Moderate	Moderate Loss of Serviceability
4	Major	Major Loss of Serviceability
5	Serious	Loss of Capacity Some Loss of Function
6	Hazardous	Major Loss of Function
7	Catastrophic	Extreme Loss of Asset

A loss or reduction of serviceability results in increased routine and/or planned maintenance or refurbishment activities for the asset. A loss or reduction in capacity is a decrease in the infrastructure's ability to resist future loading. A loss of function was defined in two ways: the loss of the infrastructure component from performing its purpose, or as a loss in ability for the hospital to provide clinical services.

The severity of the hazards was defined through a facilitated workshop.

Once the risk scores for each infrastructure/climate interaction are determined, patterns and trends in vulnerabilities can be assessed. This can lead to identifying the primary climate stressors and the systems or services that are most prone to failure. The analyses follow the general principals of root cause analysis.

Risk Assessment Workshop

A facilitated workshop was organized to identify the severity scores for each infrastructure component and climate parameter interaction. Workshop participants included Island Health Facilities, Maintenance, and Operation Staff (FMO), Facilities and Planning Managers, Clinical Practitioners, Clinical Operations Managers, a member of PCIC, and the consulting team. The purpose was to achieve a consensus-based severity score that aggregates the professional experience of the consulting team with the in-service performance knowledge of the systems of FMO staff and Island Health facilities managers.

A voting system was devised to rapidly poll all relevant experts for specific queries. All workshop attendants were provided colour coded cards identified with the severity score and description, thus permitting rapid averaging of severity scores. The voting process is shown in Figure 4-1.

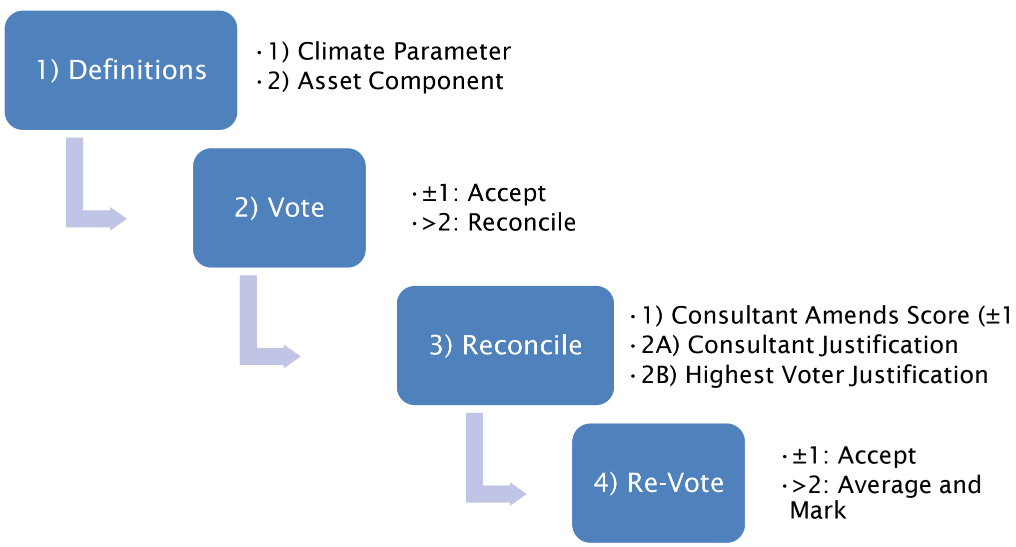

Figure 4-1 – Facilitated Workshop Concensus Building Process

First, the subconsultant discipline lead provided a definition of the climate parameter, the design threshold (e.g. 27°C design dry bulb temperature), and the hazard associated in a hypothetical situation where the design threshold is surpassed by the climate loading. This hypothetical situation did not include the issues of frequency or magnitude, as the probability scores were withheld to avoid participants conflating severity with risk.

Second, a round of voting was held and the participants' scores averaged. The consultant's severity score was then revealed, so as not to unduly influence the workshop severity score, and compared with the polled value. Scores that fell within ±1 point of the consultant's score were deemed sufficiently close and accepted. Score variations greater than 2 led to the Reconcile phase.

The Reconcile phase also permitted the consultants to either agree with the broader consensus or to provide a justification on their initial score. This phase also permitted any participants with outlier scores to justify their selection. This led to a second round of voting, resulting in either acceptance of the final vote if within ±1 point or an averaging of the consultant's and participant's score.

The result of the 0-7 probability and severity scores are multiplied to define a risk score from 0 to 49, shown in *Figure 4.2*. Through discussions with Island Health on the importance of infrastructure systems to clinical operations, it was determined that a risk score greater than 30 would represent a high priority item for the hospital. Consequently, the four classes of risk are defined as High Risk (score greater than 30), Medium Risk (greater than 10, but less than 30), Low Risk (less than 10), and Special Conditions (a score of 7, involving frequent but minor impacts, or infrequent but catastrophic impacts).

Severity of Occurrence							
7	7	14	21	28	35	42	49
6	6	12	18	24	30	36	42
5	5	10	15	20	25	30	35
4	4	8	12	16	20	24	28
3	3	6	9	12	15	18	21
2	2	4	6	8	10	12	14
1	1	2	3	4	5	6	7
	1	**2**	**3**	**4**	**5**	**6**	**7**
	Probability of Occurrence						

Figure 4.2 PIEVC Risk Score Matrix

The detailed risks scores, including the defined probability of occurrence and severity on hospital operations, may be found in Appendix C: Probability, Severity, and Risk Scores. A risk score summary is provided in Appendix D: Risk Score Summary.

4.2 Summary of Systems at Risk

This section summarizes the risk scores of the interaction between the infrastructure components and climate parameters. Only scores greater than 12 are included in the summaries.

The full list of climate parameters, and their designation numbers, are listed below:

TABLE 4.2 CLIMATE PARAMETERS	
Number Designation	Parameter
1.	Contaminated Water
2.	Heat Waves
3.	Strong Winds
4.	Storm Intensity and Frequency
5.	Warmer Winters
6.	Air Pollution (Forest Fires)
7.	Cold Snap
8.	Winter Storm (Ice Storm)
9.	Humidity
10.	Daily Temperature Range
11.	Dryer and Warmer Summers
12.	Water Shortages
13.	Sea Level Rise
14.	Warmer Domestic Supply Water
15.	Flooding

4.2.1 Mechanical

The main effects on the mechanical systems are caused by heat waves and high humidity conditions. The cooling system seems most sensitive to effects of heat waves, whereas the critical air and other ventilation systems are susceptible to air pollution (forest fires) and high humidity.

TABLE 4.3 SCORES OF THE INTERACTION BETWEEN MECHANICAL INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS						
Category	Infrastructure Component	Climate Parameter and Risk Score				
		Heat Waves	Air Pollution (Forest Fires)	Humidity	Water Shortages	Warmer Domestic Water Supply
Cooling Plant	Back-up cooling water	42			24	24
Cooling Plant	Chilled Water Pumps & Distribution	35		28		
Cooling Plant	Chillers	35		35		
Cooling Plant	Condenser Water Pumps & Distribution	35		35		
Cooling Plant	Cooling Towers	35		35	36	

TABLE 4.3 SCORES OF THE INTERACTION BETWEEN MECHANICAL INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS						
Category	Infrastructure Component	Climate Parameter and Risk Score				
		Heat Waves	Air Pollution (Forest Fires)	Humidity	Water Shortages	Warmer Domestic Water Supply
Critical Air Systems (OR, NICU, PAR, MDR)	Air Distribution (Ductwork, dampers, etc.)	28		35		
Critical Air Systems (OR, NICU, PAR, MDR)	Cooling Coils	35		42		
Critical Air Systems (OR, NICU, PAR, MDR)	Fans	21		35		
Critical Air Systems (OR, NICU, PAR, MDR)	O/A Intakes		30			
DDC System	Cooling Control Valves	14				
Food & Housekeeping Services	Refrigeration	21				
Medical Gasses	Medical Air		30	35		
Other Central Air Systems	Air Distribution (Ductwork, dampers, etc.)	21		21		
Other Central Air Systems	Cooling Coils	28		35		
Other Central Air Systems	Fans	21		21		
Other Central Air Systems	O/A Intakes		30			
Radiant Heating & Cooling Systems	Radiation and Panel Systems	14				
Thermal Plant	Boilers				36	
Unitary HVAC Systems	Rooftop Units	21	30	28		
Unitary HVAC Systems	Split Systems	21				

4.2.2 Electrical

The electrical systems appear mainly resistant to climate change parameters. Overheating of the elevator controllers and main distribution transformer during heat waves may pose some issues. Strong winds and storms may also damage BC Hydro supply. Premature failure of the electrical systems due to higher outdoor humidity is a lesser concern.

The back up power system has been reviewed by others and its capacity has been increased. The new back up power, which consists of three 1.5MW diesel generators, is designed such that is may operate continuously, provided that it is supplied with a continuous supply of fuel. As per the NRGH Electrical Energy Centre Schematic Design Report the fuel storage tanks will hold approximately 30,000 L of fuel, sufficient to supply one generators at rated output for 72 hours. Refer to the Stantec NRGH Electrical Energy Centre Schematic Design Report for complete new system capabilities.

Both the normal power distribution and the essential power generation and distribution systems are located on the ground level of the facility. This becomes a concern in the event of extreme flooding that would occur as the result of excessive downpour of rain coupled with the failure of the back-parking lot storm drainage system. The compounded risk of concurrent flooding at this location is defined in Section 4.2.6 and is considered low risk.

TABLE 4.4 SCORES OF THE INTERACTION BETWEEN ELECTRICAL INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS

Category	Infrastructure Component	Climate Parameter and Risk Score			
		Heat Waves	Strong Winds	Storm Intensity & Frequency	Humidity
Elevators	Elevator Controllers	21			
Electrical Distribution System	BC Hydro Supply		15	12	
Electrical Distribution System	Main Distribution Transformers	14			
Electrical Distribution System	Main MV Distribution Equipment				14
Electrical Distribution System	Secondary Distribution Equipment				14
Misc Elect Systems	Lighting – Exterior				14

4.2.3 Structural

The primary structural elements are resistant to a number of climate parameters. The greatest concern is from overloading of the roof from excessive precipitation downpours paired with insufficient and clogged rainwater leaders. At grade flooding may also pose a risk to the foundation or slabs-on-grade from sub-surface erosion.

TABLE 4.5 SCORES OF THE INTERACTION BETWEEN STRUCTURAL INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS					
Category	Infrastructure Component	Climate Parameter and Risk Score			
		Strong Winds	Storm Intensity & Frequency	Winter Storm (Ice Storm)	Flooding
Superstructure - Primary	Concrete Structures		18	12	
Superstructure - Primary	Foundation				16
Superstructure - Primary	Slabs				16
Superstructure - Primary	Steel Frames		18	12	
Superstructure - Primary	Wood	15	18	12	
Superstructure - Secondary	In-fill Walls	12			

4.2.4 Enclosure

The enclosure elements most susceptible to changing climate parameters are fenestration and waterproofing systems. Heat waves decrease service life of building components, and strong winds and storms can cause water ingress into the building. The greatest risk appears to be heat waves seizing the operation mechanism of the sliding glass doors from overheating.

TABLE 4.6 SCORES OF THE INTERACTION BETWEEN ENCLOSURE INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS					
Category	Infrastructure Component	Climate Parameter and Risk Score			
		Strong Winds	Storm Intensity & Frequency	Winter Storm (Ice Storm)	Flooding
Fenestration	Curtain Walls	14		12	
Fenestration	Punch Windows	14	12	12	
Fenestration	Skylights	14	12		
Fenestration	Sliding Doors	21	12		
Fenestration	Window Wall	14		12	
Finishes	Paint	14		12	
Waterproofing	Flashing				
Waterproofing	Roof Membrane	21	15	12	14
Waterproofing	Sealants	14			

4.2.5 Water

The greatest concern for domestic water systems is a systemic climate-induced water shortage, caused by warmer, dryer summers and/or less snowpack in winter. The hospital has limited control over reservoir levels and priority at the City of Nanaimo, and its lack of on-site captured and/or stored water exacerbates its risk exposure. The climate parameter of Dryer and Warmer Summer was also used as a proxy for water shortages and due to its higher probability score (7 vs 6), yields a higher risk. However, concerns related to water shortage instead use the more appropriate Water Shortage climate parameter within this section.

TABLE 4.7 SCORES OF THE INTERACTION BETWEEN WATER INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS		
Category	Infrastructure Component	Climate Parameter and Risk Score
		Water Shortages
Domestic Water System	Back-up Water Supply	24
Domestic Water System	Drinking Water Supply	30
Domestic Water System	Plumbing Fixture Supply	30
Domestic Water System	Process Water Supply	24
Domestic Water System	Quantity	24
Domestic Water System	RO Water (for labs, renal, MDRD)	30

4.2.6 Civil

Flooding poses a site access problem for some areas of the hospital, exacerbated by the positioning of retaining walls and site water shedding characteristics. However, the surface topology of the hospital property should not result in complete blockage of site access to the campus. The landscape is at risk of heat waves and water shortages which could result in dying vegetation, and strong winds could pose a threat from falling trees.

TABLE 4.8 SCORES OF THE INTERACTION BETWEEN CIVIL INFRASTRUCTURE COMPONENTS AND CLIMATE PARAMETERS							
Category	Infrastructure Component	Climate Parameter and Risk Score					
		Heat Waves	Strong Winds	Storm Intensity & Frequency	Dryer and Warmer Summers	Water Shortages	Flooding
Landscaping	Retaining Walls						20
Landscaping	Trees/Irrigation/Grass/Vegetation	21	12		14	18	
Site Access Systems	Loading Docks			12			12
Site Access Systems	Roads/Parking Areas						12

4.3 External System Climate Risk Assessment

The risk assessment summarized above focuses on those systems under the jurisdiction of Island Health, and within the physical boundaries of NRGH. Many of these systems are dependent on external services that fall outside of the campus property or authority of Island Health. Subsequent to the facilitated workshop, a break-out group with FMO managers was organized to identify how each of these external services are critical to hospital operations. These systems were then further assessed, based on the same severity criteria, on how the hospital could respond should these services no longer be provided.

Two challenges with such assessments are the intrinsic redundancy in hospital systems to overcome limited shortages, and the potential synergy between concurrent lapses in services. A shortage of diesel for the back-up generators is not an issue provided that electricity is not disrupted. However, a disruption in electricity requires the use of the generators, which have sufficient fuel storage for 3 days. Consequently, the staged effects of electricity shortages are mediated by the availability of diesel, but the overall consequence of a concurrent diesel shortage or inadequate fuel quality with a disruption in electricity is equivalent to the worst-case of the two severity scores.

To help illustrate the interconnections between the climate parameter, out-of-scope services and systems, and the within-scope services and systems, a relationship chart was created. See Figure 4.3 below.

Solid lines represent direct relationships. The colour of the line represents which discipline is typically responsible for the connection or the service. Dashed lines represent secondary relationships, mainly between services. The values below the Climate Parameters indicate the probability score, and the values below the External Service indicate the severity score of impact on hospital operations in case of disruption. The values below the Infrastructure System represent the maximum identified risk score.

The probability of occurrence of these climate parameters is not necessarily indicative of a potential risk or failure; these must be considered on a system-by-system basis. However, should the external service be disrupted, the severity scores apply to the entirety of the hospital. Consequently, the relationships help illustrate how climate change can negatively affect some of the external services, and which services are prone to multiple risk factors.

The general susceptibility of a system can be identified by the number of secondary (dependent) connections, and the primary upstream relationship. For instance, the cooling and heating systems are dependent on electricity and water, and are affected by several climate change parameters related to higher outdoor temperatures.

The key takeaways from this chart are the upstream vulnerabilities that can manifest when system dependencies are included. However, as the values within the relationship chart all represent worst-case scenarios, these dependencies are addressed within the scoring framework. Future recommendations for climate change adaptation and mitigation should take into consideration the effects of these interdependencies.

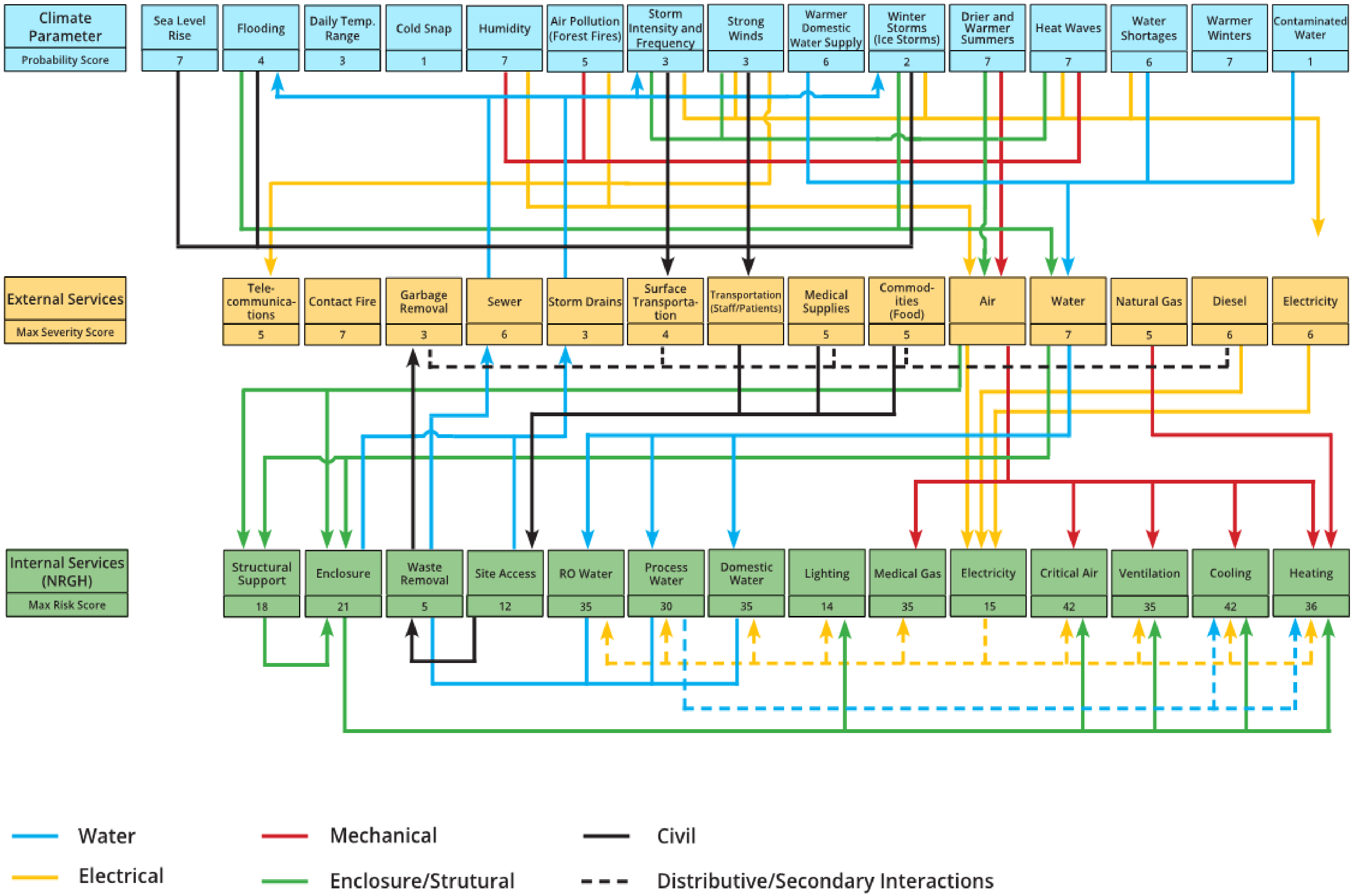

Figure 4.3 – Climate Parameter and Services Relationship Chart

5 Engineering Analysis

The PIEVC protocol uses the Engineering Analysis phase to further refine the vulnerabilities and risks of the interactions found in the Risk Assessment Phase. Generally, further analysis is required of those interactions which are not clearly defined or for which unresolved uncertainties persist. Alternatively, engineering analysis can also be used to better understand interactions that are found to be a part of a pattern of vulnerability or where additional work would help identify mitigation responses. Discussions with Island Health identified persistent concerns related to providing space conditioning and water, thus leading to conclusions that Island Health's risk tolerance threshold fell within the 30-point risk score levels. Review of the risk assessment identifies three main patterns of potential vulnerability exceeding this risk threshold: Mechanical – Cooling, Mechanical – Critical Air, and Water – Domestic Water Supply. The root-causes analysis of these systems identified the same underlying issue for Mechanical – Cooling and Mechanical – Critical Air: challenges posed by achieving cooling set-points. This section further clarifies the loads, risks, and vulnerabilities of these three systems.

5.1 Methodology

The engineering analysis phase is used to further refine the vulnerability of the three identified systems. The assessment of vulnerability follows a high-order evaluation of the current loads, the projected change in loads, and the projected change of the infrastructure components. It then assesses the capacity of the infrastructure, particularly the existing capacity, and how that capacity changes with time, if at all. Detailed assessment on the loads and capacities of each system falls beyond the scope of a climate vulnerability risk assessment. The recommendations are provided conceptually and detailed assessments would not substantially modify the conclusions.

> ***Vulnerability***:
>
> *The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.*

5.2 Mechanical – Cooling Plant

The complexity of the cooling plant, both in terms of number of components and interconnections, necessitated a simplified methodology for the engineering analysis. Island Health has engaged an engineering consultant, independent of this assessment report, to review the overall capacity and performance of the chilled water system. The general understanding is that the cooling system has some deficiencies which already adversely impact hospital operations in some areas. Some areas of the hospital, however, have been receiving adequate cooling under current climatic conditions. Beyond the overall plant capacities, individual components (noted below) have not been studied. The general approach to the cooling system analysis has therefore been high-level and qualitative.

Existing Load (L_E):

The chilled water consultant has modelled the cooling load for the facility using various assumptions such as building envelope performance and occupant loading. The existing loads are commensurate with normal cooling requirements of this vintage of hospital. Original designs relied on earlier climate data. Generally, ventilation and internal heat gains tend to be the dominant cooling load, and not solar heat gains, apart from the Tower glazing system.

Change in Loads

Projected Change in Load from Climate Changes

According to the chilled water consultant, most air system cooling coils in the hospital were designed for an outdoor air dry bulb temperature in the range of 26-27 ˚C, and wet bulb temperatures near 18 ˚C. The sensible air dry bulb and wet bulb conditions are projected to surpass 30˚C and 19.5˚C, respectively, by 2050 in the RCP 8.5 scenario. The resulting increase in cooling load has not been determined as it falls beyond the scope of a climate vulnerability assessment.

Projected Change in Load from Other Effects

The required cooling load in the hospital could be reduced from changes in occupancy, usage or through modifications of the building envelope. This cooling plant study has however assumed there will be no significant changes of any consequence, and therefore this value is assumed to be zero.

Existing Capacity

As noted above, the hospital generally has sufficient cooling capacity to handle the existing loads, although there is a lack of redundancy in some areas. The air conditioning delivery to the main “Nursing” tower is inadequate, but that is due to issues of the air distribution system and large gains. The tower only has supply air into the corridors, and the supply ducts are not insulated. No further chilled water cooling could be provided to the building as the supply ducts would start to experience condensation. However, in terms of handling the maximum cooling that could be transferred to the tower air systems, the existing load is adequate.

Change in Capacity

Projected Change in Capacity over Time

It is anticipated that the cooling study underway will lead to recommendations and implementation of chilled water system renovations that will increase the cooling plant capacity over time. This would reduce the impact from future climate changes.

Projected Change in Capacity from Other Factors

This is assumed to be zero (it is assumed that any future building additions or new buildings will address the required increase in hospital campus cooling capacity). Other factors, likely to not change in the future, include items such as room/building functions.

5.2.1 Statement of Vulnerability

It is recommended that the cooling system study currently underway be expanded in scope to include a review of the potential impact of climate change. This would include an assessment of existing cooling coil capabilities to handle increased loads, including the ability to handle climatic-related increases through lowering of chilled water supply temperatures. This would in turn require an assessment of the impact of chilled water generation (capacity) using lower supply water temperatures. In addition to chilled water temperature reset, the potential for increasing chilled water flow rates to cooling coils should be evaluated to determine whether there are any pipe size, control valve size, or pumping capacity concerns. Future renovations and expansion projects should account for the forecasted climate changes.

In summary, the cooling systems were identified as vulnerable due to increased outdoor air temperatures and relative humidity levels during summer months. These increases would impact plant cooling capacity. To reduce this vulnerability, it is recommended to carry out an air system cooling coil capacity review after the cooling study has been completed.

5.3 Mechanical – Critical Air Systems

There are several critical air systems in the hospital, each of a different vintage, capacity and degree of redundancy of components. Any capacity limitations of the chilled water plant would impact the performance of the critical air system cooling and relative humidity control. Given that the cooling system review is still underway, along with the number of air systems involved, it was again deemed necessary to use a high-level qualitative approach for the analysis. For the outdoor air intake assessment, a review of the critical air system filtration level and ability to recirculate building air were considered.

Change in Loads

The existing cooling loads have been estimated by the chilled water consultant, but air flow delivery rates (and air changes per hour) have not been assessed. Since the primary concern, relating to climatic impact, is increased outdoor air dry and wet bulb temperatures, the parameter of concern is ventilation cooling load. The total cooling load, from both the dry and wet bulb temperatures, is referred to as enthalpy. The projected change in load due to climate change is anticipated to be a linear increase in cooling coil loads as outdoor air temperature increases. The degree of increase in cooling loads falls outside the scope of this project.

In terms of the outdoor intakes, the load of concern is smoke from forest fires. Climatic projections indicate a possible increase in forest fires. This would increase the probability of there being a “smoke” loading on the outdoor air intakes.

Should room functions not vary, no significant changes in loading from other effects are anticipated.

Change in Capacity

The existing cooling coils on the whole have adequate capacity to meet existing loads, according to the cooling consultant. Some outdoor air systems have electrostatic air filtration, which according to hospital staff has been somewhat successful in eliminating or reducing smoke and other odours brought in through the outdoor air intakes. Further smoke removal efficiencies might be obtained through the addition of high efficiency particulate (HEPA) filters although these have significant pressure losses which might affect total air flow rates unless fan speeds and possibly motor sizes were increased. Few of the air systems have any means of full air recirculation, a strategy used by some healthcare facilities during local forest fires (or other fires/smoke incidents). Smoke control in critical air systems is therefore deficient.

The chilled water consultant has indicated that the existing cooling coil capacity could be increased by reducing the chilled water supply temperature. This would increase utility costs, but would afford some increase in cooling capacity. The potential impact of this strategy has not been evaluated.

5.3.1 Statement of Vulnerability

It is recommended that an engineering feasibility study be undertaken to determine the costs of incorporating full air recirculation for critical air systems, in the case of a local forest fire. Room pressure relationships should be assessed for any recirculation strategy. The study should also take into consideration operable windows and air infiltration. Regarding air infiltration, improvements to the air barrier systems could be addressed through enclosure improvements. Reductions in leakage would reduce cooling loads (where air conditioning is provided) although it is unlikely that this would be significant due to high ventilation air requirements.

For those critical air systems that do not have electrostatic filtration, filtration systems should be upgraded to accommodate this feature.

It is also recommended that a study be conducted to determine the capacity of cooling coil performance with higher enthalpy loads in the future. This review could be carried out under the cooling plant study mentioned above.

In summary, critical air systems were identified as vulnerable due to the anticipated influences from higher summertime outdoor air temperatures and relative humidity as well as smoke intake. A cooling coil capacity review, in concert with the cooling system review, is recommended. Air filtration upgrades should be carried out to mitigate concerns about smoke from fires affecting the performance and air quality of these critical air systems.

5.4 Water – Domestic Water Supply

While individual climate asset pairings associated with the domestic water system were generally scored as “medium risk”, the water system collectively showed a pattern of vulnerability associated with climate-induced water shortage. For this reason, additional discussion is included regarding loads, capacity, and recommendations specific to this system.

Change in Loads

The hospital property is connected to the City of Nanaimo (CON) watermains on Boundary Avenue near the Water Service Building. A second watermain connection is indicated off Nelson Road and enters the property between the FMO building and the Kiwanis Village Property. The onsite water infrastructure appears to generally be in good working condition. With annual flushing and maintenance, the existing primary water distribution loop can last up to 100 years.

Domestic water load is not expected to increase dramatically within the existing facilities. In fact, a decrease in load may be realized as the plumbing fixture replacement program continues. The system as designed is adequate to meet its current and projected loads, barring a large-scale expansion.

Change in Capacity

Water is supplied by the CON. The CON reservoir is retained by the South Fork Dam which has approximately 17 million cubic metres of live storage. The CON has ample water supply for current demands. The 2007 CON Water Supply Strategic Plan[1], which included considerations for climate change, indicated that more supply may be required between 2020 and 2025. The need for additional storage is dependent on population growth and consumer user rates. According to CON staff, the need for additional storage will be re-assessed in the near future.

The region's ability to meet its domestic water demand in the face of climate-induced water shortage does have the potential to impact hospital operations. In this sense, this is a regional capacity issue as well as a site-specific capacity issue.

Local rainfall is expected to increase with the changing climate; however, the variation is biased seasonally. It is anticipated that increased rainfall will occur in winter, but reduced rainfall will occur in summer.

5.4.1 Statement of Vulnerability

The CON is monitoring current use and reservoir levels to determine when reservoir expansion is required. However, NRGH can consider the following recommendations to make the facility less vulnerable to external factors, as well as to reduce demand on the regional infrastructure. This in turn will make the whole region more resilient to climate change impacts.

Reducing the strain on regional domestic water supply is a critical component in ensuring increased water availability for hospital operations. This should be achieved by ensuring that there is no remaining once-through cooling (including for backup), and to consider accelerating the plumbing fixture replacement program – in particular, focus on replacing original water closets and urinals.

Additional work should include an Investigation into the feasibility of installing a non-potable water system to serve non-potable water needs; for example, cooling tower make-up water and other process loads, and landscape irrigation. An investigation into the feasibility of emergency on-site potable water storage for short term shortage events and/or on-site wells should also be considered, to provide adaptive capacity in case of water shortages.

[1] City of Nanaimo Water Resources – Water Supply Strategic Plan, Associated Engineering, January 2007, https://www.nanaimo.ca/docs/services/water-and-sewage/watersupplystrategicplan-1.pdf

6 Conclusions and Recommendations

6.1 Conclusions

The results of the PIEVC protocol assessment for NRGH demonstrate several critical trends of climate change vulnerability to the existing infrastructure. The three climate parameters that are responsible for most of the medium and high-risk interactions are Heat Waves, Humidity, and Water Shortages. The three primary systems found vulnerable to climate change are the Cooling Plant, the Critical Air Systems, and the Domestic Water System. The first two systems are affected primarily by being unable to satisfy the required cooling demand of the building, whereas municipal-level water shortages are the primary concern for the latter.

The climate models suggest a strong probability of occurrence for many of the air temperature related climate parameters. The increase in air temperature, and the concomitant increased saturated vapour pressure, result in higher outdoor air enthalpy. These effects conspire to decrease the Cooling Plant System functionality during heat waves, as the heat rejection devices, mainly evaporating coils and cooling towers, are strained under the warmer and more humid outdoor air.

The Critical Air systems are similarly challenged in providing sufficient cooling to maintain appropriate indoor air conditions. With the decreased capacity of the cooling plant, the associated distribution system and terminal coils may be unable to meet demand. The effects are further exacerbated by the ventilation requirements and the higher outdoor enthalpy, resulting in decreased sensible cooling.

The secondary effects of warmer air temperatures and drier summers result in increased risk of regional forest fires. The reduced air quality from high particulate loads can overload the filters that feed into the Critical Air System.

Drier summers and warmer temperatures also add pressure to domestic water availability. The local reservoirs not only provide potable and medical process water, but are also used in mechanical systems for back-up cooling and make-up water. However, the City of Nanaimo water reservoir falls outside of the jurisdiction of Island Health, and requires external discussions with the municipality to address water shortage concerns. This may involve negotiations on maintaining priority during drought conditions.

6.2 Recommendations

The Recommendations section is divided into three parts. Section 6.2.1 discusses conceptual recommendations for NRGH, with respect to the infrastructure risks and vulnerable systems. Section 6.2.2 discusses some challenges and recommendations for improvements of the PIEVC protocol, devised by the Adaptation to Climate Change Team at Simon Fraser University. Section 6.2.3 provides broad-level recommendations on climate change adaptation and mitigation. Specific recommendations for each at-risk system may be found in Appendix A: Infrastructure Risk and Recommendations.

6.2.1 Recommendations for NRGH

The PIEVC protocol sets out a methodology to identify interactions between infrastructure components and changing climate parameters; it then provides guidance on estimating the probability and severity of these interactions to yield a risk result. The medium and high-risk items can then be addressed as part of a renewal strategy for the hospital. However, not every system can be rehabilitated immediately due to logistic and cost limitations. Further, with changing hospital operations, replacement or addition of new systems, or expansion with new hospital wings, future PIEVC protocol assessments will be required to evaluate these changing infrastructure components. To resolve these issues, this iteration of the Nanaimo Regional General Hospital Report will use the VFA Assets Detail Report from 2012 to help prioritize the recommendations. The assets identified as due for renewals within a 10-year period have been given priority, as generally, these are all items identified as Priority 1- Currently Critical, or 2 – Potentially Critical.

Some identified high-risk systems have sufficiently long remaining service lives that they are not contained within the VFA asset prioritization list. However, some of the climate change time horizons are sufficiently long that these items will come up for renewal prior to achieving the full magnitude of the projected climate parameter. Consequently, the systems that are due for renewal within the short-term take precedence in order to take advantage of the economic benefits of combined planned renewals and adaptation measures. The renewed systems must accommodate current climate loads while also being able to adapt to the future climate loads. Those systems that are not captured in this study can be identified in future PIEVC assessment iterations, and when combined with the VFA asset condition data, can be updated to handle future environmental conditions.

VFA Asset Management and PIEVC Protocol Assessment

The VFA Asset Inventory reports prioritize renewals based on the remaining service life of the identified assets and the overall importance in building operations. For the purposes of this assessment, only those items that have been identified as requiring renewal work within the next 10 years are considered as higher priority candidates for climate adaptation measures. This consists of *Immediate* and *Within 10 Year* priorities in accordance with Action Date defined in the VFA Asset Detail Report (2012). From an asset management perspective, the *Immediate* renewal items should be acted upon as soon as reasonably possible, but from the context of climate mitigation and adaptation, any item within 10 years are of approximate equivalent priority. The priority list is shown in Table 6.1. Any highly vulnerable systems that are not captured within the current renewal time horizon should be considered in subsequent renewals/adaptation work. Future PIEVC assessments may further refine prioritization of these remaining systems.

TABLE 6.1 INFRASTRUCTURE COMPONENT RISK AND VFA PRIORITY				
Division	Category	Infrastructure Component	Highest Risk Score	VFA Priority
Civil	Landscaping	Trees/Irrigation/Grass/Vegetation	21	Within 10 Years
Electrical	Misc. Elect. Systems	Lighting – Exterior	14	Immediately
Electrical	Electrical Distribution System	Main Distribution Transformers	14	Within 10 Years
Enclosure	Waterproofing	Roof Membrane	21	Immediately
Enclosure	Waterproofing	Sealants	14	Immediately
Enclosure	Fenestration	Punch Windows	14	Within 10 Years
Enclosure	Fenestration	Skylights	14	Within 10 Years
Enclosure	Finishes	Paint	14	Within 10 Years
Mechanical	Cooling Plant	Cooling Towers	36	Immediately
Mechanical	Unitary HVAC Systems	Split Systems	21	Immediately
Mechanical	DDC Systems	Cooling Control Valves	14	Immediately
Mechanical	Cooling Plant	Back-up Cooling Water	42	Within 10 Years
Mechanical	Critical Air Systems	Fans	42	Within 10 Years
Mechanical	Cooling Plant	Chilled Water Pumps & Distribution	35	Within 10 Years
Mechanical	Cooling Plant	Chillers	35	Within 10 Years
Mechanical	Critical Air Systems	Cooling Coils	35	Within 10 Years
Mechanical	Other Central Air Systems	Cooling Coils	35	Within 10 Years
Mechanical	Other Central Air Systems	Fans	21	Within 10 Years
Structural	Superstructure – Primary	Concrete Structures	18	Within 10 Years
Water	Domestic Water Supply	Drinking water supply/plumbing fixture supply/RO Water	35	Within 10 Years

Many of these VFA recommendations involve replacement or renewal of systems that are currently beyond their service lives. By incorporating the climate adaptation recommendations as part of the renewal process, only the incremental costs for the engineering related climate adaptation measure are incurred. The recommendations associated with the VFA prioritization list for each respective discipline are provided in Table 6.2 to Table 6.7.

TABLE 6.2 MECHANICAL SYSTEM – RECOMMENDATIONS	
COOLING PLANT	
1	It is recommended that the cooling system study currently underway be expanded in scope to include a review of the potential impact of climate change. This would include an assessment of existing cooling coil capabilities to handle increased loads, including the potential ability to handle climatic increases through lowering of chilled water supply temperatures. This would in turn require an assessment of the impact of chilled water generation (capacity) using lower supply water temperatures. In addition to chilled water temperature reset, the potential for increasing chilled water flow rates to cooling coils should be evaluated to determine whether there are any pipe size, control valve size, or pumping capacity concerns.
CRITICAL AIR SYSTEMS	
2	It is recommended to have an engineering feasibility study undertaken to determine the costs of incorporating full air recirculation for critical air systems, in the case of a local forest fire. Room pressure relationships should be assessed for any recirculation strategy. The study should also take into consideration operable windows and air infiltration. For those critical air systems which do not have electrostatic filtration, filtration systems should be upgraded to accommodate this feature.
OTHER CENTRAL AIR SYSTEMS	
3	Conduct a cooling system review as an extension to the chilled water study. After reviewing cooling coil capabilities (with forecasted weather data), determine whether increased air flow rates are required to meet projected loads and maintain relative humidity levels and whether increased cooling loads can be addressed by lowering chilled water supply temperatures. Following the recommended chilled water coil study, determine if required air flow rates need to be increased to meet new demands from climatic changes.
UNITARY HVAC SYSTEMS	
4	Review rooftop unit and split system cooling/dehumidification capacities during scheduled equipment replacement and replace with higher capacity units as required.
DDC SYSTEM	
7	Following the recommended cooling coil assessment study, establish whether increased chilled water flow rates would be required to meet projected loads. Thereafter review capacity and pressure drop of existing cooling coil control valves.

TABLE 6.3 ENCLOSURE SYSTEM – RECOMMENDATIONS	
FENESTRATION	
11	Monitor condition of sealants around windows and verify for signs of failed IGUs (fogging), which indicate a drainage issue of the window frame or window sealant failure.
12	Monitor windows for signs of damage and replace as necessary. Ensure windows are maintained in accordance with maintenance schedules. In future window replacement projects, improvement to the waterproofing and air sealing of the window opening should be included as part of this work (e.g. inclusion of sub-sill flashing). Careful consideration on the appropriate Solar Heat Gain Coefficients (SHGC) must be considered to reduce solar gains, as well as using the lowest U-value windows possible, to minimize heat transfer. Operable windows with limiters should be considered to permit ventilation in case of cooling system disruption.

WATERPROOFING	
15	Annual roof inspections can help identify reduced service life issues, such as degranulation, crazing, and bowing of the roof membrane. These inspections pre-empt reduced service life concerns and can be planned for renewal prior to critical failures. On future roof membrane replacements, consideration should be made to increase the thermal insulation on the roof. This insulation can reduce enclosure space conditioning loads while also improving the drainage. Additionally, consideration for low-albedo roofs should also be included as part of this work, to extend the service life of the roof membrane and reduce solar heating gains.
16	Ensuring proper function of the roof drains is a critical factor in minimizing precipitation load on the roof membrane. Including roof drains as part of regular maintenance can help reduce risk of roof water ponding.
17	Monitor conditions and replace sealants at critical enclosure joints as required or in accordance with maintenance schedules.
FINISHES	
18	Ensure exterior finishes are maintained in accordance with maintenance plans and schedules.

TABLE 6.4 STRUCTURAL SYSTEM – RECOMMENDATIONS	
SUPERSTRUCTURE (PRIMARY)	
19	A remedial action for roof loads consists of ensuring adequate roof sloping to drain rainwater. A managerial recommendation is to ensure roof drains are cleaned and maintained in accordance with maintenance schedule.

TABLE 6.5 CIVIL SYSTEM – RECOMMENDATIONS	
LANDSCAPING	
30	Review health of vegetation during prolonged dry periods and flooding incidents. If prolonged heat periods destroy vegetation, replace with mixture of drought and flood tolerant species, depending on local topology. Ensure low-ground cover near to buildings to mitigate fire-risk.
32	Assess strength and health of trees regularly and remove limbs if in poor condition. Assess potential for trees to fall into buildings, property, and pedestrian areas. Remove trees deemed to have high-fall potential. Retain professional arborist to review trees and assess the need for their removal to protect buildings, property, and the public.

TABLE 6.6 WATER SYSTEM – RECOMMENDATIONS	
DOMESTIC WATER SUPPLY	
34	Consider an accelerated plumbing fixture replacement program to reduce potable water consumption and strain on regional domestic water supply – in particular, focus on replacing original water closets and urinals. Ensure there is no remaining once-through cooling (including for backup). Consider installing a non-potable water system to serve non-potable water needs; for example, cooling tower make-up water and other process loads, and landscape irrigation. Consider on-site potable water storage for short term shortage events.
36	Reduce potable water consumption for non-potable uses and/or ensure that critical potable water uses have priority in water shortage events.

TABLE 6.7 ELECTRICAL SYSTEM – RECOMMENDATIONS	
ELECTRICAL DISTRIBUTION SYSTEM	
40	Monitor power loading on each transformer and ensure loading does not exceed approximately 40%. This will ensure that if the facility is operating on one transformer, it will be able to support the load under adverse conditions (such as higher temperatures).
MISCELLANEOUS ELECTRICAL	
43	Monitor structural pole conditions and have a structural engineering provide schedule for replacement.

Recommendations for all other components with risk scores greater than 10 may be found in Appendix A: Infrastructure Risk and Recommendations. A study on the synergy between many of these infrastructure systems may be beneficial to optimize their interactions and be included as part of their renewals work.

6.2.2 PIEVC Recommendations

The PIEVC protocol is a valuable tool for conducting climate change risk assessments. To date, the protocol has been used primarily on civil infrastructure systems, such as culverts, bridges, and to an extent, some buildings. The NRGH constitutes the first applications of the PIEVC protocol to a large and complex building campus with unique requirements to fulfill its prime function of providing medical services to the local community.

Hierarchical Systems

A major challenge in using the PIEVC protocol for complex systems is the issue of defining risk for hierarchical infrastructure systems, multiple sub-systems, duplicate systems that experience different climate loads, and system redundancies. This issue exhibited primarily in determination of the probability scores (different sub-systems may have different levels of exposure) and severity scores (system redundancy reduces apparent severity, which discounts the actual consequences for a failure). The secondary challenge of hierarchical infrastructure systems is ownership and jurisdictional authority. Critical systems that fall outside of the control of the owner, such as electrical power supply (BC Hydro), or natural gas (FortisBC), may have upstream vulnerabilities that cannot be adequately addressed within the scope of this project.

This high-level approach works well for identifying the risk to a larger-scale system, but the probability, severity, and risk assessments are not necessarily valid at finer resolution or scales. A potential solution is divide the risk scores according to differing levels of system failures (e.g. first level failure: redundant system functional, second level failure: back-up systems functional, third level failure: all systems offline). However, this further complicates the probability/severity scoring system, as multiple scores are assigned to each sub-system for different climatic parameters at different levels of failure. Resolution with a 'failure coefficient' may simplify this issue, albeit at the cost of transparency and accountability. Further study to the problem of hierarchical systems is warranted.

Integrated Climate Change Effects

The concept of vulnerability to climate impacts is characterized in three main ways: physical exposure to extreme or gradually changing average conditions; sensitivity to this exposure; and capacity to respond in both proactive and reactive ways. Comprehensive climate risk and resilience assessments therefore require consideration and integration of a wide variety of physical, socio-economic, and place-specific climate impacts.

Some impacts will be experienced as individual extreme events (e.g. major rainstorms, heatwaves); some as slow-onset, long-term problems (e.g. sea level rise, population displacement); and others that result from impacts in neighbouring regions (e.g. a storm results in a loss of services/amenities in a nearby city, or a major health issue in a remote area drives victims to a city centre). Climate change planning also considers the possibility of cascading impacts, and of these risks happening simultaneously. In order to develop an effective resilience plan, all these factors require analysis and consideration, as do actions being taken by other jurisdictions. Guidance on how to incorporate secondary climate change effects would be beneficial in guiding future adaptation efforts.

Operational Actions

It is also important to recognize that management, maintenance, and operational practices can exacerbate or mitigate the impacts of climate risks. Risk and vulnerability assessment should therefore extend to decision-making practices, operating guidelines, and emergency planning. For instance, the planning process for future facility upgrades or expansions should include mandatory consideration for adaptation and mitigation strategies, or procurement could include additional requirements for energy efficiency on new clinical equipment.

Climate change projections are being updated on an ongoing basis with continually improving levels of detail. Resilience should therefore be viewed as a process, not a specific target, and there is increasing recognition of the need for adaptive planning in terms of managing this process. Adaptation actions tend to be place- and context-specific, so no single approach can be considered effective across all settings (IPCC, 2014). However, adaptation is becoming more commonplace across a variety of disciplines. The PIEVC Protocol, while useful as a standalone output, might be especially beneficial if included as part of a larger-scale, comprehensive, climate risk and resilience framework.

There are several tools being used to assess climate change vulnerability and resilience that allow for inclusion of the factors outlined above. One such example is the Building Adaptive and Resilient Communities (BARC) tool from the International Council for Local Environmental Initiatives (ICLEI) Canada for municipalities. It is currently being expanded for use in public sector organizations. The Canadian Coalition for Green Health Care also has a climate change resiliency toolkit and may warrant further investigation.

As of yet, there is no single tool available in Canada that integrates emissions and energy efficiency planning with resilience planning. The Adaptation to Climate Change Team at Simon Fraser University has provided below a five-stage general adaptation process. The PIEVC process would represent a component of Stage 2 in this approach. In practice, stages may overlap, and some elements such as monitoring/review, and stakeholder engagement, may run throughout, as they do in the ISO 31000:2009 Risk Management Framework. This process should include low carbon and energy efficiency considerations throughout:

1. Build Awareness of Climate Change and Commitment to Adaptation:
   Develop organizational awareness of climate change impacts by participation in

research or networks, and commit to adaptation through, for example, the appointment of a cross-functional steering committee and champion to encourage action.

2. Understand Impacts and Assess Risks:
Undertake vulnerability and risk assessments to understand how climate change impacts may affect the organization, and prioritize key concerns. May include modelling and scenario planning and evidence from actual climate conditions and building impacts.

3. Plan and Implement Adaptation Strategy:
Plan and evaluate adaptation actions using structured decision making and other tools, and implement using best practices.

4. Monitor Progress and Review Approach:
Ensure approaches remain flexible in the face of new information and a changing climate, and value continuous improvement philosophy and adaptive management.

5. Consult Throughout:
Involve stakeholders and rights holders at each stage to incorporate a broad range of perspectives, facilitate coordination, and build buy-in.

6.2.3 Climate Change Adaptation Recommendations

There are a variety of significant climate change resilience concerns and approaches that fall outside of the pure engineering focus and scope of the PIEVC protocol, but which are nevertheless integrally linked with, and influence, the physical risks and resilience of NRGH. Addressing these concerns, as part of a comprehensive climate risk and resilience analysis, could help tie the PIEVC results into the broader emergency planning and resilience initiatives that the hospital is engaged in, and/or that may be advisable next steps as part of Island Health's climate resilience planning. The following is not an exhaustive set of recommendations, but is intended to evoke further research and discussion related to holistic climate change resilience planning for NRGH:

1. Identify Synergies between Mitigation and Adaptation Planning and Actions (Low Carbon Resilience)

As a public-sector organization, Island Health will be responsible for developing 10-year mitigation and adaptation plans to meet the mandated requirements of the new BC Climate Leadership Plan. Hospitals tend to have a large environmental footprint, yet, given their central regional role, they also have unique potential to provide leadership and serve as community anchors and role models for sustainability actions. Incorporating low carbon resilience by integrating planning for climate change resilience with energy efficiency (and other aspects of carbon management) offers a variety of co-benefits and synergies, including saving time and financial resources. Such an approach could model climate leadership approaches for the region.

For example, existing hospital strategies related to renewable energy, energy efficiency, and related infrastructure upgrades can and should be assessed for resilience. Likewise, the resilience measures, identified as recommended outcomes from the PIEVC analysis, should be assessed for their greenhouse gas contributions. The sourcing and disposal of products/materials, food, and water can also be analyzed to ensure the hospital is achieving low carbon resilient practices.

Some measures are inherently low carbon resilient - for example, green infrastructure options such as bio-swales, rain gardens and green roofs store carbon, cool the surrounding area (reducing the urban heat island effect and its impacts as well as the need for energy-intensive air conditioning), and provide precipitation/flood absorption. These options can also provide health benefits and crucial habitat for pollinators. Low carbon energy systems, such as district energy installations, tend to be more resilient. They reduce reliance on a central grid, and facilities that conserve and recycle energy and water can operate longer on reserve supplies. A low carbon resilience analysis could therefore be a beneficial next step for the NRGH facility and other Island Health operations.

2. Address Broader Resilience Concerns

Patient Flow and Capacity Monitoring

Monitoring and projection of climate change trends and associated health impacts such as extreme heat events, wildfire, flooding, and increased prevalence of diseases (e.g. Lyme disease, Zika virus, West Nile virus) can help to inform patient flow analysis and highlight associated internal capacity issues. The monitoring of hospital visits for respiratory issues following wildfires and extreme heat events by the BC Centre for Disease Control (BCCDC) is an example of the type of early warning and alert system that NRGH could become connected with. Climate change is also projected to drive the emergence of new health risks that might affect the hospital's capacity to operate.

This type of monitoring and analysis could be strengthened by incorporating demographic projections for climate change-based migration in the region. For instance, Nanaimo has been designated by the Government of Canada as a community that welcomes Syrian refugees and a city that contains ample service provider organizations, and an influx of people to the region (for instance, as a result of climate change displacing populations in other countries) in coming years could impact hospital resources, services, capacity and patient flow patterns.

"Last Building Standing" and Supplies Capacity

Hospitals are often designated as high importance post-disaster buildings and should therefore be prepared to serve as community hubs for food, water, shelter, power, and resources during and after extreme events. Specific patient types may also be disproportionately affected and require additional resilience planning – for example, New York hospitals received an unusually large number of patients seeking emergency dialysis treatment following Hurricane Sandy.

Additional Access and Location Issues

Vehicle/ambulance access to the hospital site is an imperative, and roads and routes that connect to the site can be impacted by extreme events, especially flooding. Given the hospital's island location, other modes of transportation such as boats and helicopters may also be impacted under certain climate change scenarios. Valuable (and often irreplaceable) items, such as samples and data, often rely on refrigeration and cooling processes that can be affected by power outages, floods, and other threats. Hazardous chemicals, depending on their location, can also be exposed to floodwaters and cause contamination problems for both the hospital and the surrounding community. Inoperable windows can be problematic if hospitals cooling systems are unable to operate on emergency power generation systems. In the event of system failures, it is also vital that plans are in place to evacuate patients and staff from key hospital locations, and provide emergency treatment services over extended periods.

Regional Climate Change Planning

Given the hospital's importance for regional well-being, and the fact that some of the considerations above will also be the subject of planning by various levels of government, NGOs and community groups, Island Health could augment NRGH climate resilience by enhancing capacity for community communication and collaboration, as well as facilitating inclusion of these factors into NRGH planning for physical climate risks. Other regional considerations include, for instance, impacts to hospital capacity resulting from the loss of municipal services and interruption of essential infrastructure networks such as telecommunications.

7 Closure

We trust that the methodologies employed in this assessment were rigorously applied and that the consequent conclusions and recommendations will prove beneficial to NRGH as it continues to fulfill and expand its vital community role in the face of a changing climate.

Yours truly,

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Appendix A: Infrastructure Risk and Recommendations

Appendix A - Infrastructure Risk and Recommendations

As part of step 2 of the PIEVC Protocol, data were gathered pertaining to the infrastructure components of the hospital. The RDH team established a list of infrastructure components to be assessed for vulnerability to climate change events. Preliminary documents were reviewed and considered in determining this list, including components identified by Island Health (Appendix A of RFP), the VFA Asset Inventories, as-built drawings and other supporting information. A site visit was conducted on March 2, 2017 to review the hospital's infrastructure conditions as well as interviewing with FMO staff. The site-visit resulted in reviewing the existing infrastructure systems in conjunction with discussions with FMO staff on remaining service life, prior history, common problems, and anticipated renewals.

The infrastructure components provided by Island Health in Appendix A of the RFP were organized into six categories and were overseen by appropriate personnel on the team: mechanical, enclosure, structure, civil, water and electrical. Additional components were chosen based on identified VFA assets and further assessment by technical personnel, to establish a comprehensive list of infrastructures vulnerable to climate change. The following sections present the list of infrastructure components that were assessed in each category, as well as other information relevant to the operation and management of the infrastructure, including climate variables that components are susceptible to, the highest probability (P), severity (S), and risk (R) score of that interaction (P, S, R), and recommendations to mitigate any risk. High risk interactions are highlighted in red. Infrastructure with no climate change interactions, or with risk scores less than 10, are indicated by an N/A score, as these are very low priority items.

A.1 Mechanical

TABLE A-1 MECHANICAL SYSYEMS: THERMAL PLANT INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Boilers	Water Shortages	A water shortage can cause the boilers to be shut-down should there be insufficient make-up water. This thus results in heating issues for the entire campus. Water shortages, however, tend to occur during summer months when heating demands are at their lowest.	P: 6 S: 6 R: 36

THERMAL PLANT RECOMMENDATIONS	
N/A	No action required at this time.

TABLE A-2 MECHANICAL SYSYEMS: COOLING PLANT INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Back-up Cooling Water	Heat Waves	Heat waves, if long enough, could increase the City's domestic water temperatures beyond the bounds of effectiveness for back-up cooling. The result would be a loss of the back-up cooling system with a failure of the overall cooling system to provide air conditioning, should there be a chiller system failure. Since this chiller system is "distributed", with multiple chillers, once full interconnection has been put in place (as planned), the degree of severity would be reduced.	P: 7 S: 6 R: 42
	Warmer Domestic Water Supply	The capacity of the back-up cooling water system, which uses service/domestic water, is limited by the water temperature. At some point, the back-up water supply temperature would be higher than that needed for adequate air conditioning, resulting in the back-up system being rendered ineffective.	P: 6 S: 4 R: 24
	Water Shortages	A shortage of water supply to the facility would likely result in some form of water rationing. If back-up cooling water use was placed at a lower priority over washrooms, sterilization, etc., then supply to the back-up cooling may have to be curtailed. The result would be a loss of cooling capabilities, during a chiller system failure.	P: 6 S: 6 R: 36
Chilled Water Pumps & Distribution	Heat Waves	It is generally expected that pipes and pumps will be able to handle increases in cooling loads from higher DB temperatures, but if additional cooling were sufficient to require higher chilled water flows, and chiller discharge temperatures could not be lowered due to chiller capacity restrictions, then pumps and pipes may be undersized. The net result would be a deficiency in cooling capacity and elevated room temperatures during "heat waves."	P: 7 S: 5 R: 35
	Humidity	As with an increase in DB temperatures, increases in WB temperatures, beyond current design, would result and higher cooling demands, higher water flow rate demands, and, if not met, would result in higher room temperatures.	P: 7 S: 4 R: 28
Chillers	Heat Waves	Depending on the degree of DB temperature exceeding design conditions, especially for critical air system cooling, the overall cooling system could fall short of the total chiller system capacity. The result would be elevated room temperatures, exceeding those recommended by CSA Z317.2.	P: 7 S: 5 R: 35
	Humidity	High wet bulb (WB) temperatures would increase overall cooling demand. If the increased demand was higher than the chilled system capacity, room temperatures would become elevated, possibility beyond the maximum allowable in CSA Z317.1.	P: 7 S: 5 R: 35

TABLE A-2 MECHANICAL SYSYEMS: COOLING PLANT INFRASTRUCTURE RISK DESCRIPTION			
Condenser Water Pumps & Distribution	Heat Waves	An increase in condenser water demand would result in higher condenser water flow rate requirements. If those elevated requirements could not be met by the pump and piping infrastructure, there would be inadequate cooling system capabilities, resulting in elevated room temperatures (beyond CSA Z317.2 bounds).	P: 7 S: 5 R: 35
	Humidity	As with an increase in DB temperatures, increases in WB temperatures, beyond current design, would result and higher cooling demands, higher water flow rate demands, and, if not met, would result in higher room temperatures.	P: 7 S: 4 R: 28
Cooling Towers	Heat Waves	Although wet bulb (WB) temperatures are significantly more critical to cooling tower performance, an elevation of DB temperature during heat waves could increase cooling demands and thus heat rejection demands. The final result would be a reduction in cooling system capacity with potential elevated room temperatures.	P: 7 S: 5 R: 35
	Humidity	WB temperatures are critical to cooling tower capacities. A sufficient increase in WB temperatures could result in severe heat rejection shortages, resulting in reduced cooling capabilities and elevated room temperatures.	P: 7 S: 5 R: 35
	Water Shortages	Water shortages necessitate a prioritization of the use of water to essential systems. The cooling tower is used as the main heat rejection device for the hospital cooling systems. Make-up water is required to replenish losses from evaporation. Should this water not be replenished, the effectiveness of the cooling tower would decrease, resulting in lowered performance of the cooling systems. Potentially, these systems may not longer be able to meet the interior cooling setpoints.	P: 6 S: 6 R: 36

COOLING PLANT RECOMMENDATIONS	
1	It is recommended that the cooling system study currently underway be expanded in scope to include a review of the potential impact of climate change. This would include an assessment of existing cooling coil capabilities to handle increased loads, including the potential ability to handle climatic increases through lowering of chilled water supply temperatures. This would in turn require an assessment of the impact of chilled water generation (capacity) using lower supply water temperatures. In addition to chilled water temperature reset, the potential for increasing chilled water flow rates to cooling coils should be evaluated to determine whether there are any pipe size, control valve size, or pumping capacity concerns.

TABLE A-3 MECHANICAL SYSYEMS: CRITICAL AIR SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Air Distribution	Heat Waves	If elevated O/A temperatures required an increase in air flow rates to introduce more cooling to spaces/rooms, and the existing ductwork was too small, air static pressures would increase, and the associated supply fans would not be able to deliver the air flows required to satisfy the space temperature requirements.	P: 7 S: 4 R: 28
	Humidity	As with DB temperature increases, increased WB temperatures could result in increased air flow demands, which, if not met, would result in higher room temperatures.	P: 7 S: 5 R: 35
Cooling Coils	Heat Waves	Cooling coil capacity is the first line of defence against increased air conditioning needs from heat waves. If cooling coil cooling capacities could not meet the elevated cooling demands during a heat wave, no revisions to air flow or water flow rates would help. The final result would be higher room temperatures, a concern especially for critical air systems.	P: 7 S: 5 R: 35
	Humidity	If cooling coils would not have sufficient total cooling capacity (sensible plus latent), the resulting supply air temperature conditions would be insufficient to meet room temperature requirements and also result in higher humidity levels, potentially exceeding the upper bounds of relative humidity in CSA Z317.1	P: 7 S: 6 R: 42
Fans	Heat Waves	Heat waves would increase cooling loads. If the cooling demands required an increase in supply air flow rates, this may not be met with the existing fan system. The final result would be an increase in room temperatures.	P: 7 S: 3 R: 21
	Humidity	Higher WB temperatures would increase cooling load, which may require an increase in supply air flow rates. If not met, room temperatures would be elevated.	P: 7 S: 5 R: 35
O/A Intakes	Air Pollution (Forest Fires)	Smoke intake, of sufficient concentration, could result in curtailment of the air system.	P: 5 S: 6 R: 30

CRITICAL AIR SYSTEMS RECOMMENDATIONS	
2	It is recommended to have an engineering feasibility study undertaken to determine the costs of incorporating full air recirculation for critical air systems, in the case of a local forest fire. Room pressure relationships should be assessed for any recirculation strategy. The study should also take into consideration operable windows and air infiltration. For those critical air systems which do not have electrostatic filtration, filtration systems should be upgraded to accommodate this feature.

TABLE A-4 MECHANICAL SYSYEMS: OTHER CENTRAL AIR SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Air Distribution	Heat Waves	If elevated O/A temperatures required an increase in air flow rates to introduce more cooling to spaces/rooms, and the existing ductwork was too small, air static pressures would increase, and the associated supply fans would not be able to deliver the air flows required to satisfy the space temperature requirements.	P: 7 S: 3 R: 21
	Humidity	As with DB temperature increases, increased WB temperatures could result in increased air flow demands, which, if not met, would result in higher room temperatures.	P: 7 S: 3 R: 21
Cooling Coils	Heat Waves	Cooling coil capacity is the first line of defence against increased air conditioning needs from heat waves. If cooling coil cooling capacities could not meet the elevated cooling demands during a heat wave, no revisions to air flow or water flow rates would help. The final result would be higher room temperatures, a concern especially for critical air systems.	P: 7 S: 4 R: 28
	Humidity	If cooling coils would not have sufficient total cooling capacity (sensible plus latent), the resulting supply air temperature conditions would be insufficient to meet room temperature requirements and also result in higher humidity levels, potentially exceeding the upper bounds of relative humidity in CSA Z317.1	P: 7 S: 5 R: 35
Fans	Heat Waves	Heat waves would increase cooling loads. If the cooling demands required an increase in supply air flow rates, this may not be met with the existing fan system. The final result would be an increase in room temperatures.	P: 7 S: 3 R: 21
	Humidity	Higher WB temperatures would increase cooling load, which may require an increase in supply air flow rates. If not met, room temperatures would be elevated.	P: 7 S: 5 R: 35
O/A Intakes	Air Pollution (Forest Fires)	Smoke intake, of sufficient concentration, could result in curtailment of the air system.	P: 5 S: 6 R: 30

OTHER CENTRAL AIR SYSTEMS RECOMMENDATIONS	
3	Conduct a cooling system review as an extension to the chilled water study. After reviewing cooling coil capabilities (with forecasted weather data), determine whether increased air flow rates are required to meet projected loads and maintain relative humidity levels and whether increased cooling loads can be addressed by lowering chilled water supply temperatures. Following the recommended chilled water coil study, determine if required air flow rates need to be increased to meet new demands from climatic changes.

TABLE A-5 MECHANICAL SYSYEMS: UNITARY HVAC SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
RTUs and Split Systems	Heat Waves	Higher O/A temperatures would only impact the outdoor air condenser performance.	P: 7 S: 3 R: 21

UNITARY HVAC SYSTEMS RECOMMENDATIONS	
4	Review rooftop unit and split system cooling/dehumidification capacities during scheduled equipment replacement and replace with higher capacity units as required.
5	Add electrostatic filtration to units which are lacking this feature.

TABLE A-6 MECHANICAL SYSYEMS: EXHAUST SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Exhaust Systems & Isolation Rooms	N/A	No interactions	N/A

TABLE A-7 MECHANICAL SYSYEMS: RADIANT HEATING & COOLING SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Cooling Panels	Heat Waves	Cooling panel performance would be reduced during a heat wave, but these are only supplemental cooling systems.	P: 7 S: 2 R: 14

RADIANT HEATING & COOLING SYSTEMS RECOMMENDATIONS	
6	For dual-cycle radiant panels, review whether increases in relative humidity (from air system performance changes) which would require adjustment to the radiant panel cooling supply water temperature set point. (It would be possible to decommission perimeter heating-only panel systems where building envelope improvements were made, but it is recommended to continue to provide perimeter heating capabilities until the end of the panel life. Each area of concern would have to be individually assessed.)

TABLE A-8 MECHANICAL SYSYEMS: DDC SYSTEM INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Cooling Control Valves	Heat Waves	If cooling loads were to increase due to heat waves, the required chilled water flow rate increases may result in higher pressure drops through the control valves, limiting chilled water flow rates. The final result would be elevated room temperatures.	P: 7 S: 2 R: 14

DDC SYSTEM RECOMMENDATIONS	
7	Following the recommended cooling coil assessment study, establish whether increased chilled water flow rates would be required to meet projected loads. Thereafter review capacity and pressure drop of existing cooling coil control valves.

TABLE A-9 MECHANICAL SYSYEMS: FOOD & HOUSEKEEPING SERVICE INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Refrigeration	Heat Waves	As with split systems, condensing units, if located outdoors, would likely have little performance difficulties with elevated O/A temperatures.	P: 7 S: 3 R: 21

FOOD & HOUSEKEEPING SERVICE RECOMMENDATIONS	
8	When condensing units are due for replacement, assess whether the current cooling capacities will suffice to handle anticipated climatic conditions.

TABLE A-10 MECHANICAL SYSYEMS: MEDICAL GASSES INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Medical Air	Air Pollution (Forest Fires)	Smoke intake, if not treated, would require shutdown of the medical air system, although backup bottles could be used until depleted.	P: 5 S: 6 R: 30
	Humidity	Although very unlikely, if higher humidity levels resulted in a deficiency in air dryer performance, it is possible that the medical air system would be operated outside of the CSA bounds for moisture content. The evaporator on the O_2 unit reportedly freezes in high dew-point conditions. Higher humidity conditions could further exacerbate this problem.	P: 7 S: 5 R: 30

MEDICAL GASSES RECOMMENDATIONS	
9	It is recommended to continue to make plans for on-site production of oxygen. The associated design should consider potential forest fire smoke and increases in outdoor air temperature and relative humidity. The existing medical air intake should be modified to allow the use of a temporary filtration system (e.g., HEPA filters) during smoke conditions.
10	Provide HEPA filtration for medical air intake, comes with bypass.

A.2 Enclosure

TABLE A-11 ENCLOSURE SYSTEMS: FENESTRATION INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Curtain Walls	Heat Waves	Extended and more intense heat waves can result in reduced service life caused by faster depolymerisation of the sealants used in windows. These polymers include the seals around the insulated glazing unit, small-joint sealant at the mitred window frames, and sealant of the window frame to the building.	P: 7 S: 2 R: 14
	Storm Intensity & Frequency	Increased storm intensity, the combination of heavier rains and wind, can overwhelm the internal drainage system of windows. This results in a risk of increased occurrences of rain leaks.	P: 3 S: 4 R: 12
Punch Windows	Heat Waves	Extended and more intense heat waves can result in reduced service life caused by faster depolymerisation of the sealants used in windows. These polymers include the seals around the insulated glazing unit, small-joint sealant at the mitred window frames, and sealant of the window frame to the building.	P: 7 S: 2 R: 14
	Storm Intensity & Frequency	Increased storm intensity, the combination of heavier rains and wind, can overwhelm the internal drainage system of windows. This results in a risk of increased occurrences of rain leaks.	P: 3 S: 4 R: 12
	Strong Winds	Strong winds could result in displacement of the window frame, resulting in damage to the continuity of the sealant. Extreme gusts, or carried debris, could also result in glazing fractures.	P: 3 S: 4 R: 12
Skylights	Heat Waves	Extended and more intense heat waves can result in reduced service life caused by faster depolymerisation of the sealants used in windows. These polymers include the seals around the insulated glazing unit, small-joint sealant at the mitred window frames, and sealant of the window frame to the building.	P: 7 S: 2 R: 14
	Strong Winds	Strong winds could result in displacement of the window frame, resulting in damage to the continuity of the sealant. Extreme gusts, or carried debris, could also result in glazing fractures. Skylights are further susceptible to uplift forces.	P: 3 S: 4 R: 12
Sliding Doors	Heat Waves	Extended and more intense heat waves can result in reduced service life caused by faster depolymerisation of the polymer sealants used in windows. These polymers include the seals around the insulated glazing unit, small-joint sealant at the mitred window frames, and sealant of the window frame to the building. The operating mechanism of the sliding glass door at the main entrance of the hospital reportedly malfunctions at warmer summer temperatures. The mechanism of failure is unknown	P: 7 S: 3 R: 21
	Strong Winds	Strong winds could result in displacement of the window frame, resulting in damage to the continuity of the sealant. Extreme gusts, or carried debris, could also result in glazing fractures.	P: 3 S: 4 R: 12
Window Wall	Heat Waves	Extended and more intense heat waves can result in reduced service life caused by faster depolymerisation of the polymer sealants used in windows. These polymers include the seals around the insulated glazing unit, small-joint sealant at the mitred window frames, and sealant of the window frame to the building.	P: 7 S: 2 R: 14

TABLE A-11 ENCLOSURE SYSTEMS: FENESTRATION INFRASTRUCTURE RISK DESCRIPTION			
	Storm Intensity & Frequency	Increased storm intensity, the combination of heavier rains and wind, can overwhelm the internal drainage system of windows. This results in a risk of increased occurrences of rain leaks.	P: 3 S: 4 R: 12

FENESTRATION RECOMMENDATIONS	
11	Monitor condition of sealants around windows and verify for signs of failed IGUs (fogging), which indicate drainage issue of the window frame or window sealant failure.
12	Monitor windows for signs of damage and replace as necessary. Ensure window are maintained in accordance with maintenance schedules. In future window replacement projects, improvement to the waterproofing and air sealing of the window opening should be included as part of this work (e.g. inclusion of sub-sill flashing). Careful consideration on the appropriate Solar Heat Gain Coefficients (SHGC) must be considered, to reduce solar gains, as well as using the lowest U-value windows possible, to minimize heat transfer. Operable windows with limiters should be considered to permit ventilation in case of cooling system disruption.
13	Conduct investigation into cause of malfunction of sliding door mechanism which reportedly fails at high temperature.

TABLE A-12 ENCLOSURE SYSTEMS: WATERPROOFING INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Flashing	Storm Intensity & Frequency	Increased wind driven rain and precipitation can overwhelm some sealant/coating systems resulting in localized leaks.	P: 3 S: 4 R: 12
Roof Membrane	Drier & Warmer Summers	Warmer summers may lead to reduced service life from higher roof membrane temperatures.	P: 7 S: 2 R: 14
	Heat Waves	Extended or extreme heat waves can result in higher roof membrane surface temperatures. This can lead to advanced depolymerisation and thermal stresses which could reduced service life of the roof membrane. These reductions in service life should not manifest as a failure if maintenance and renewal schedules are followed.	P: 7 S: 3 R: 21
	Storm Intensity & Frequency	Increased wind driven rain and precipitation can overwhelm some sealant/coating systems resulting in localized leaks, particularly at mechanical penetrations, vents, and perimeter parapet cap flashings.	P: 3 S: 4 R: 12
	Strong Winds	Extreme uplift may cause bond or mechanical failure in roofing system membrane. Ballasted roofs may see displacement of the ballast resulting in decreased hold-down capacity and as a risk of projectiles. Wind uplift may place additional stresses on seams and joints in the roof membrane creating the potential for leaks.	P: 3 S: 5 R: 15
Sealants	Heat Waves	Extended or extreme heat waves can result in higher roof membrane surface temperatures. This can lead to advanced depolymerisation and thermal stresses which could create reduced service life of the roof membrane.	P: 7 S: 2 R: 14

WATERPROOFING RECOMMENDATIONS	
14	Risks of water penetrations into the walls are best resolved with remedial actions involving the installation of through-wall flashings at areas known to be prone to leaks. These through-wall flashing intercept and divert water within the wall assembly to the exterior. This can form part of a rehabilitation project. This recommendation only applies to veneered or clad wall systems.
15	Annual roof inspections can help identify reduced service life issues, such as degranulation, crazing, and bowing of the roof membrane. These inspections pre-empt reduced service life concerns and can be planned for renewal prior to critical failures. On future roof membrane replacements, consideration should be made to increase the thermal insulation on the roof. This insulation can reduce enclosure space conditioning loads while also improving the drainage. Additionally, consideration for low-albedo roofs should also be included as part of this work, to extend the service life of the roof membrane and reduce solar heating gains.
16	Ensuring proper function of the roof drains is a critical part in minimize precipitation load on the roof membrane. Including roof drain as part of regular maintenance can help reduce risk of roof water ponding.
17	Monitor conditions and replace sealants at critical enclosure joints as required or in accordance with maintenance schedules.

TABLE A-13 ENCLOSURE SYSTEMS: FINISHES INFRASTRUCTURE RISK DESCRIPTION

Asset	Climate Susceptibility	Description of Interaction	PSR
Paint	Heat Waves	Increased temperatures generally result in decreased service life of building finishes, mainly polymer based paints.	P: 7 S: 2 R: 14

FINISHES RECOMMENDATIONS	
18	Ensure exterior finishes are maintained in accordance with maintenance plans and schedules.

TABLE A-14 ENCLOSURE SYSTEMS: INSULATION INFRASTRUCTURE RISK DESCRIPTION

Asset	Climate Susceptibility	Description of Interaction	PSR
Insulation	N/A	No interactions	N/A

TABLE A-15 ENCLOSURE SYSTEMS: PENETRATION INFRASTRUCTURE RISK DESCRIPTION

Asset	Climate Susceptibility	Description of Interaction	PSR
Walls /Roof	N/A	No interactions	N/A

TABLE A-16 ENCLOSURE SYSTEMS: VAPOUR/AIR BARRIERS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Walls/Roof/ Foundation	N/A	No interactions	N/A

TABLE A-17 ENCLOSURE SYSTEMS: MISCELLANEOUS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Chemical Storage/ Hazardous Materials	N/A	No interactions	N/A

A.3 Structural

TABLE A-18 STRUCTURAL SYSTEMS: SUPERSTRUCTURE (PRIMARY) INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Concrete Structures	Storm Intensity & Frequency	Increased rain loads, particularly rain on snow combined with blocked roof drains, may result in overloading situations. An overloaded roof may result in excessive deflections and cracking in concrete structures, and could result in collapse in lighter-weight roofing systems, such as open-webbed steel joists or wood framed structures.	P: 3 S: 6 R: 18
	Winter Storm (Ice Storm)	Similar to Storm Intensity and Frequency, overloading created by rain on snow with blocked roof drains can result in a risk of structural damage to overloading.	P: 2 S: 6 R: 12
Foundation /Slabs	Flooding	Flooding scenarios can apply significant lateral hydraulic loads to foundations, potentially resulting in cracks or lateral displacement. Slabs on grade may be undercut by water flows.	P: 4 S: 4 R: 16
Steel Frames	Storm Intensity & Frequency	Increased rain loads, particularly rain on snow combined with blocked roof drains, may result in overloading situations. An overloaded roof may result in excessive deflections and cracking in concrete structures, and could result in collapse in lighter-weight roofing systems, such as open-webbed steel joists or wood framed structures.	P: 3 S: 6 R: 18
	Winter Storm (Ice Storm)	Similar to Storm Intensity and Frequency, overloading created by rain on snow with blocked roof drains can result in a risk of structural damage to overloading.	P: 2 S: 6 R: 12
Wood	Storm Intensity & Frequency	Increased rain loads, particularly rain on snow combined with blocked roof drains, may result in overloading situations. An overloaded roof may result in excessive deflections and cracking in concrete structures, and could result in collapse in lighter-weight roofing systems, such as open-webbed steel joists or wood framed structures.	P: 3 S: 6 R: 18
	Strong Winds	Concrete and steel structures are generally controlled by seismic lateral loads, not wind loads. However, the lighter weight wood structures on the campus are susceptible to higher lateral loads. Extreme gusts may cause damage to wood framed walls.	P: 3 S: 5 R: 15
	Winter Storm (Ice Storm)	Similar to Storm Intensity and Frequency, overloading created by rain on snow with blocked roof drains can result in a risk of structural damage to overloading.	P: 2 S: 6 R: 12

SUPERSTRUCTURE (PRIMARY) RECOMMENDATIONS	
19	A remedial action for roof loads consists of ensuring adequate roof sloping to drain rainwater. A managerial recommendation is to ensure roof drains are cleaned and maintained in accordance with maintenance schedule.
20	Damage to wood structures is best resolved by monitoring actions. This involves checking for evidence of damage or displacement, such as cracks in interior finishes (greater than 2mm), or windows or doors that jam. Remedial actions should be taken subsequent to investigation by qualified structural experts.
21	Detailed flood plain mapping is required to obtain a better understanding of floor risks to the foundations and slabs of the building. Flood risks can be minimized by ensuring perimeter and storm-water drains are routinely scoped, cleaned, and kept operations.

TABLE A-19 STRUCTURAL SYSTEMS: SUPERSTRUCTURE (SECONDARY) INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
In-fill Walls	Strong Winds	Secondary structural elements may be at risk from high winds creating high uplift or lateral forces. This mainly manifests as damage to the attachment to the primary structure, but may also result in localized failure of the secondary structural accessories.	P: 3 S: 4 R: 12

SUPERSTRUCTURE (SECONDARY) RECOMMENDATIONS	
22	In-fill walls should be monitored for signs of damage or cracking. Evidence of damage should manifest as cracks in the drywall (2mm or greater) or windows or doors that jam. Remedial actions should be taken subsequent to investigation by qualified structural experts.

A.4 Civil

TABLE A-20 CIVIL SYSTEMS: SITE ACCESS SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Loading Docks	Flooding	Storm sewer backup and/or waterway surcharging could prevent access to the loading docks.	P: 4 S: 3 R: 12
	Storm Intensity & Frequency	Increased rainfall, snowfall in combination with peak winds will increase runoff leading to increased scour, increased snow removal requirements and increased wind-borne debris clearing.	P: 3 S: 4 R: 12
Roads/Parking Areas	Flooding	Storm sewer backup and/or waterway surcharging could loosen base gravels and undermine structural support of site access components.	P: 4 S: 3 R: 12

SITE ACCESS SYSTEMS RECOMMENDATIONS	
23	Review condition of site access systems and performance of storm systems after significant precipitation events.
24	Create maintenance management activity to review site after storm events.
25	Conduct a CCTV inspection and flushing of all underground storm drain components to ensure system is at peak performance.
26	Conduct a storm water analysis to ensure system capacity for increased intensity.
27	Review site conditions after ice storms and assess damaged areas, if any. Create maintenance management activity to review site after ice storm events and identify areas of concern, if any.
28	Review condition of site accesses after a flooding incident. Review causes of flooding occurrence. Identify solution to flooding.
29	Ensure catch basins are routinely inspected and regularly cleaned. Ensure storm drains are flushed twice annually and inspected with CCTV every 2 to 5 years (frequency depends on observations).

TABLE A-21 CIVIL SYSTEMS: FIRE SUPPRESSION SYSTEM INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Fire Hydrants	Contaminated Water	Risk score less than 10	P: 1 S: 1 R: 1
	Winter Storm (Ice Storm)	Risk score less than 10	P: 2 S: 3 R: 6
	Humidity	Risk score less than 10	P: 7 S: 1 R: 7

TABLE A-22 CIVIL SYSTEMS: WASTE STORAGE AND REMOVAL INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Kitchen Waste	Contaminated Water	Risk score less than 10	P: 1 S: 5 R: 5

TABLE A-23 CIVIL SYSTEMS: SANITARY SEWER INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Acid Neutralizer & Grease Interceptors	N/A	No interactions	N/A

TABLE A-24 CIVIL SYSTEMS: LANDSCAPING INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Retaining Walls	Flooding	Storm sewer backup and/or waterway surcharging could saturate soils, cause stress to vegetation and provide high groundwater loading to retaining walls.	P: 4 S: 5 R: 20
Trees/Irrigation/ Grass/Vegetation	Drier & Warmer Summers	Extended periods of time degree-days hotter than normal will stress vegetation and increase risk of fire.	P: 7 S: 2 R: 14
	Heat Waves	Extended periods of time degree-days hotter than normal will stress vegetation and increase risk of fire.	P: 7 S: 3 R: 21
Trees/Irrigation/ Grass/Vegetation	Drier & Warmer Summers	Higher wind loading over longer periods of time than normal has the potential for large trees to fall over and for limbs to break away.	P: 3 S: 4 R: 12
	Water Shortages	Extended periods of time without precipitation will stress vegetation and increase risk of fire.	P: 6 S: 3 R: 18

LANDSCAPING RECOMMENDATIONS	
30	Review health of vegetation during prolonged dry periods and flooding incidents. If prolonged heat periods destroy vegetation, replace with mixture of drought and flood tolerant species, depending on local topology. Ensure low-ground cover near to buildings to mitigate fire-risk.
31	Review retaining walls for signs for stress (cracks). Review causes of flooding occurrence. Identify solution to flooding.
32	Assess strength and health of trees regularly and remove limbs if in poor condition. Assess potential for trees to fall into buildings, property, and pedestrian areas. Remove trees deemed to have high-fall potential. Retain professional arborist to review trees and assess the need for their removal to protect buildings, property, and the public.
33	Review site conditions after ice storms and peak storm events, assess the need for drainage and/or pruning requirements. Create maintenance management activity to review site after ice storm/peak storm events and identify areas of concern, if any. Retain professional arborist to review trees and assess the need for risk of impact due to falling limbs from ice/wind.

A.5 Water

TABLE A-25 WATER SYSTEMS: DOMESTIC WATER SUPPLY INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Back-up Water Supply	Drier & Warmer Summers	Dryer and warmer summers will impact water supply, which, if severe, can impact the ability of NRGH to meet all of its potable water demand.	P: 7 S: 2 R: 14
	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 4 R: 24
Drinking Water Supply	Drier & Warmer Summers	Dryer and warmer summers will impact water supply, which, if severe, can impact the ability of NRGH to meet all of its potable water demand.	P: 7 S: 5 R: 35
	Flooding	Potential increased on-site treatment needed if water is contaminated (e.g. increased turbidity from intense storm event)	P: 4 S: 6 R: 24
	Storm Intensity & Frequency	Potential increased on-site treatment needed if water is contaminated (e.g. increased turbidity from intense storm event)	P: 3 S: 6 R: 18
	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 5 R: 30
Plumbing Fixture Supply	Drier & Warmer Summers	Dryer and warmer summers will impact water supply, which, if severe, can impact the ability of NRGH to meet all of its potable water demand.	P: 7 S: 5 R: 35
	Flooding	Potential increased on-site treatment needed if water is contaminated (e.g. increased turbidity from intense storm event)	P: 4 S: 6 R: 24
	Storm Intensity & Frequency	Potential increased on-site treatment needed if water is contaminated (e.g. increased turbidity from intense storm event)	P: 3 S: 6 R: 18
	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 5 R: 30
Process Water Supply	Drier & Warmer Summers	Dryer and warmer summers will impact water supply, which, if severe, can impact the ability of NRGH to meet all of its potable water demand.	P: 7 S: 2 R: 14
	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 5 R: 30
Water Quantity	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 4 R: 24

TABLE A-25 WATER SYSTEMS: DOMESTIC WATER SUPPLY INFRASTRUCTURE RISK DESCRIPTION			
RO Water	Drier & Warmer Summers	Dryer and warmer summers will impact water supply, which, if severe, can impact the ability of NRGH to meet all of its potable water demand.	P: 7 S: 5 R: 35
	Water Shortages	If severe or long-term, water shortages can impact the ability of NRGH to meet all of its potable water demand.	P: 6 S: 5 R: 30

DOMESTIC WATER SUPPLY RECOMMENDATIONS	
34	Consider an accelerated plumbing fixture replacement program to reduce potable water consumption and strain on regional domestic water supply – in particular, focus on replacing original water closets and urinals. Ensure there is no remaining once-through cooling (including for backup). Consider installing a non-potable water system to serve non-potable water needs; for example, cooling tower make-up water and other process loads, and landscape irrigation. Consider on-site potable water storage for short term shortage events.
35	Evaluate City of Nanaimo's ability to treat high turbidity events and compare against turbidity limits of NRGH equipment.
36	Reduce potable water consumption for non-potable uses and/or ensure that critical potable water uses have priority in water shortage events.

TABLE A-26 WATER SYSTEMS: STORM WATER MANAGEMENT SYSTEMS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Ground Level Storm Water Drainage	Flooding	Flooding may exceed capacity of ground level drainage	P: 4 S: 5 R: 20
	Storm Intensity & Frequency	Heavy rainfall events may exceed capacity of ground level drainage.	P: 3 S: 5 R: 15
	Winter Storm (Ice Storm)	Freezing followed by heavy rain could lead to blocked drainage	P: 2 S: 6 R: 12
Permeable Cover, Bioswales	Flooding	Flooding will likely exceed capacity of infiltration drainage	P: 4 S: 5 R: 20
	Storm Intensity & Frequency	Heavy rainfall events likely to exceed capacity of infiltration drainage.	P: 3 S: 5 R: 15
	Winter Storm (Ice Storm)	Freezing followed by heavy rain could lead to blocked drainage	P: 2 S: 6 R: 12
Roof Drains	Flooding	Rain induced flooding may exceed capacity of roof drains.	P: 4 S: 5 R: 20
	Storm Intensity & Frequency	Increased precipitation volumes could overwhelm roof drains, potentially resulting in roofing leaks result in roofing leaks.	P: 3 S: 5 R: 15
	Winter Storm (Ice Storm)	Freezing followed by heavy rain could lead to blocked drainage, burst pipes; combined with other storm events, could lead to roof failure	P: 2 S: 7 R: 14

STORMWATER MANAGEMENT SYSTEMS RECOMMENDATIONS	
37	Evaluate the condition and capacity of all roof drains and rainwater leaders with respect to likely future rain events. The roof drainage system should be upgraded as needed in tandem with planned roof membrane replacement work, which was scheduled in the VFA report for 2017 (for both Tower and Rehab buildings). Further engineering analysis would be required and could be completed as part of an enclosure condition assessment.
38	Evaluate condition and capacity of ground level drainage to absorb heavier rainfall events.

A.6 Electrical

TABLE A-27 ELECTRICAL SYSTEMS: DISTRIBUTION SYSTEM INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
BC Hydro Supply	Storm Intensity & Frequency	Utility outages due to downed power lines, lightning strikes etc.	P: 3 S: 4 R: 12
	Strong Winds	Utility outages due to downed power lines or utility equipment failure	P: 3 S: 5 R: 15
Main Distribution Transformers	Heat Waves	With increased ambient heat the possibility of transformer failure also increases. The present operation shares the load on both transformers thereby operating well below rated levels with little risk of failure due to heat waves. The concern is should a transformer fail during a heat wave one transformer will be required to service the facility. If operating close to full load along with high temperatures will significantly increase its possibility of failure resulting in a full system shut down.	P: 7 S: 2 R: 14
Distribution Equipment	Humidity	With higher humidity degradation of operating surfaces will occur. Due to the limited operation binding could occur preventing operation of the switches/breakers.	P: 7 S: 2 R: 14

DISTRIBUTION SYSTEM RECOMMENDATIONS	
39	Ensure emergency power system are maintained and connected to critical systems, in accordance with maintenance plans.
40	Monitor power loading on each transformer and ensure loading does not exceed approximately 40%. This will ensure that if the facility is operating on one transformer, it will be able to support the load under adverse conditions (such as higher temperatures).
41	Maintain regulator maintenance on the equipment at least every 3 years. Report should be monitored noting any degradation in equipment operation.

TABLE A-28 ELECTRICAL SYSTEMS: BACK-UP GENERATORS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Capacity	N/A	No interactions	N/A
Location	Flooding	Risk score less than 10	P: 4 S: 1 R: 4

TABLE A-28 ELECTRICAL SYSTEMS: BACK-UP GENERATORS INFRASTRUCTURE RISK DESCRIPTION			
Fuel Oil Storage & Delivery	N/A	No interactions	N/A

TABLE A-29 ELECTRICAL SYSTEMS: LIFE SAFETY INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Fire Alarm System	N/A	No interactions	N/A

TABLE A-30 ELECTRICAL SYSTEMS: COMMUNICATIONS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Data Cabling Network	N/A	No interactions	N/A
Nurse Call	Heat Waves	Risk score less than 10	P: 7 S: 1 R: 7
Security Systems	Heat Waves	Risk score less than 10	P: 7 S: 1 R: 7
Server Room	N/A	No interactions	N/A
Site Service for Tele/Com	N/A	No interactions	N/A
UPS System	Heat Waves	Risk score less than 10	P: 7 S: 1 R: 7

TABLE A-31 ELECTRICAL SYSTEMS: ELEVATORS INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Elevators	Heat Waves	Based on prolonged heat waves resulting in high operating temperatures, electronic equipment failure is possible.	P: 7 S: 3 R: 21
ELEVATOR RECOMMENDATIONS			
42	Monitor room operating temperatures to ensure room remain at or lower than 24˚C.		

TABLE A-32 ELECTRICAL SYSTEMS: MISCELLANEOUS ELECTRICAL INFRASTRUCTURE RISK DESCRIPTION			
Asset	Climate Susceptibility	Description of Interaction	PSR
Exterior Lighting	Humidity	Poles rust faster thereby reducing rated life expectancy.	P: 7 S: 2 R: 14
Interior Lighting	N/A	No interactions	N/A
MISCELLANEOUS ELECTRICAL RECOMMENDATIONS			
43	Monitor pole condition and have a structural engineering provide schedule for replacement.		

A.7 Summary of Recommendations

Table A-33 presents a summary of recommendations from the preceding sections. Recommendations for infrastructure components with a VFA priority of "Immediate" or "Within 10 Years" are highlighted in red.

TABLE A-33 SUMMARY OF RECOMMENDATIONS	
THERMAL PLANT	
N/A	No action required at this time.
COOLING PLANT	
1	It is recommended that the cooling system study currently underway be expanded in scope to include a review of the potential impact of climate change. This would include an assessment of existing cooling coil capabilities to handle increased loads, including the potential ability to handle climatic increases through lowering of chilled water supply temperatures. This would in turn require an assessment of the impact of chilled water generation (capacity) using lower supply water temperatures. In addition to chilled water temperature reset, the potential for increasing chilled water flow rates to cooling coils should be evaluated to determine whether there are any pipe size, control valve size, or pumping capacity concerns.
CRITICAL AIR SYSTEMS	
2	It is recommended to have an engineering feasibility study undertaken to determine the costs of incorporating full air recirculation for critical air systems, in the case of a local forest fire. Room pressure relationships should be assessed for any recirculation strategy. The study should also take into consideration operable windows and air infiltration. For those critical air systems which do not have electrostatic filtration, filtration systems should be upgraded to accommodate this feature.
OTHER CENTRAL AIR SYSTEMS	
3	Conduct a cooling system review as an extension to the chilled water study. After reviewing cooling coil capabilities (with forecasted weather data), determine whether increased air flow rates are required to meet projected loads and maintain relative humidity levels and whether increased cooling loads can be addressed by lowering chilled water supply temperatures. Following the recommended chilled water coil study, determine if required air flow rates need to be increased to meet new demands from climatic changes.
UNITARY HVAC SYSTEMS	
4	Review rooftop unit and split system cooling/dehumidification capacities during scheduled equipment replacement and replace with higher capacity units as required.
5	Add electrostatic filtration to units which are lacking this feature.
RADIANT HEATING & COOLING SYSTEMS	
6	For dual-cycle radiant panels, review whether increases in relative humidity (from air system performance changes) which would require adjustment to the radiant panel cooling supply water temperature set point. (It would be possible to decommission perimeter heating-only panel systems where building envelope improvements were made, but it is recommended to continue to provide perimeter heating capabilities until the end of the panel life. Each area of concern would have to be individually assessed.)
DDC SYSTEM	
7	Following the recommended cooling coil assessment study, establish whether increased chilled water flow rates would be required to meet projected loads. Thereafter review capacity and pressure drop of existing cooling coil control valves.
FOOD & HOUSEKEEPING SERVICE	
8	When condensing units are due for replacement, assess whether the current cooling capacities will suffice to handle anticipated climatic conditions.

TABLE A-33 SUMMARY OF RECOMMENDATIONS	
MEDICAL GASSES	
9	It is recommended to continue to make plans for on-site production of oxygen. The associated design should consider potential forest fire smoke and increases in outdoor air temperature and relative humidity. The existing medical air intake should be modified to allow the use of a temporary filtration system (e.g., HEPA filters) during smoke conditions.
10	Provide HEPA filtration for medical air intake, comes with bypass.
FENESTRATION	
11	Monitor condition of sealants around windows and verify for signs of failed IGUs (fogging), which indicate drainage issue of the window frame or window sealant failure.
12	Monitor windows for signs of damage and replace as necessary. Ensure window are maintained in accordance with maintenance schedules. In future window replacement projects, improvement to the waterproofing and air sealing of the window opening should be included as part of this work (e.g. inclusion of sub-sill flashing). Careful consideration on the appropriate Solar Heat Gain Coefficients (SHGC) must be considered, to reduce solar gains, as well as using the lowest U-value windows possible, to minimize heat transfer. Operable windows with limiters should be considered to permit ventilation in case of cooling system disruption.
13	Conduct investigation into cause of malfunction of sliding door mechanism which reportedly fails at high temperature.
WATERPROOFING	
14	Risks of water penetrations into the walls are best resolved with remedial actions involving the installation of through-wall flashings at areas known to be prone to leaks. These through-wall flashing intercept and divert water within the wall assembly to the exterior. This can form part of a rehabilitation project. This recommendation only applies to veneered or clad wall systems.
15	Annual roof inspections can help identify reduced service life issues, such as degranulation, crazing, and bowing of the roof membrane. These inspections pre-empt reduced service life concerns and can be planned for renewal prior to critical failures. On future roof membrane replacements, consideration should be made to increase the thermal insulation on the roof. This insulation can reduce enclosure space conditioning loads while also improving the drainage. Additionally, consideration for low-albedo roofs should also be included as part of this work, to extend the service life of the roof membrane and reduce solar heating gains.
16	Ensuring proper function of the roof drains is a critical part in minimize precipitation load on the roof membrane. Including roof drain as part of regular maintenance can help reduce risk of roof water ponding.
17	Monitor conditions and replace sealants at critical enclosure joints as required or in accordance with maintenance schedules.
FINISHES	
18	Ensure exterior finishes are maintained in accordance with maintenance plans and schedules.
SUPERSTRUCTURE (PRIMARY)	
19	A remedial action for roof loads consists of ensuring adequate roof sloping to drain rainwater. A managerial recommendation is to ensure roof drains are cleaned and maintained in accordance with maintenance schedule.
20	Damage to wood structures is best resolved by monitoring actions. This involves checking for evidence of damage or displacement, such as cracks in interior finishes (greater than 2mm), or

TABLE A-33 SUMMARY OF RECOMMENDATIONS	
	windows or doors that jam. Remedial actions should be taken subsequent to investigation by qualified structural experts.
21	Detailed flood plain mapping is required to obtain a better understanding of floor risks to the foundations and slabs of the building. Flood risks can be minimized by ensuring perimeter and storm-water drains are routinely scoped, cleaned, and kept operations.
SUPERSTRUCTURE (SECONDARY)	
22	In-fill walls should be monitored for signs of damage or cracking. Evidence of damage should manifest as cracks in the drywall (2mm or greater) or windows or doors that jam. Remedial actions should be taken subsequent to investigation by qualified structural experts.
SITE ACCESS SYSTEMS	
23	Review condition of site access systems and performance of storm systems after significant precipitation events.
24	Create maintenance management activity to review site after storm events.
25	Conduct a CCTV inspection and flushing of all underground storm drain components to ensure system is at peak performance.
26	Conduct a storm water analysis to ensure system capacity for increased intensity.
27	Review site conditions after ice storms and assess damaged areas, if any. Create maintenance management activity to review site after ice storm events and identify areas of concern, if any.
28	Review condition of site accesses after a flooding incident. Review causes of flooding occurrence. Identify solution to flooding.
29	Ensure catch basins are routinely inspected and regularly cleaned. Ensure storm drains are flushed twice annually and inspected with CCTV every 2 to 5 years (frequency depends on observations).
LANDSCAPING	
30	Review health of vegetation during prolonged dry periods and flooding incidents. If prolonged heat periods destroy vegetation, replace with mixture of drought and flood tolerant species, depending on local topology. Ensure low-ground cover near to buildings to mitigate fire-risk.
31	Review retaining walls for signs for stress (cracks). Review causes of flooding occurrence. Identify solution to flooding.
32	Assess strength and health of trees regularly and remove limbs if in poor condition. Assess potential for trees to fall into buildings, property, and pedestrian areas. Remove trees deemed to have high-fall potential. Retain professional arborist to review trees and assess the need for their removal to protect buildings, property, and the public.
33	Review site conditions after ice storms and peak storm events, assess the need for drainage and/or pruning requirements. Create maintenance management activity to review site after ice storm/peak storm events and identify areas of concern, if any. Retain professional arborist to review trees and assess the need for risk of impact due to falling limbs from ice/wind.
DOMESTIC WATER SUPPLY	
34	Consider an accelerated plumbing fixture replacement program to reduce potable water consumption and strain on regional domestic water supply – in particular, focus on replacing original water closets and urinals. Ensure there is no remaining once-through cooling (including for backup). Consider installing a non-potable water system to serve non-potable water needs; for example, cooling tower make-up water and other process loads, and landscape irrigation. Consider on-site potable water storage for short term shortage events.

TABLE A-33 SUMMARY OF RECOMMENDATIONS	
35	Evaluate City of Nanaimo's ability to treat high turbidity events and compare against turbidity limits of NRGH equipment.
36	Reduce potable water consumption for non-potable uses and/or ensure that critical potable water uses have priority in water shortage events.
STORMWATER MANAGEMENT SYSTEMS	
37	Evaluate the condition and capacity of all roof drains and rainwater leaders with respect to likely future rain events. The roof drainage system should be upgraded as needed in tandem with planned roof membrane replacement work, which was scheduled in the VFA report for 2017 (for both Tower and Rehab buildings). Further engineering analysis would be required and could be completed as part of an enclosure condition assessment.
STORMWATER MANAGEMENT SYSTEMS (CONT'D)	
38	Evaluate condition and capacity of ground level drainage to absorb heavier rainfall events.
ELECTRICAL DISTRIBUTION SYSTEM	
39	Ensure emergency power system are maintained and connected to critical systems, in accordance with maintenance plans.
40	Monitor power loading on each transformer and ensure loading does not exceed approximately 40%. This will ensure that if the facility is operating on one transformer, it will be able to support the load under adverse conditions (such as higher temperatures).
41	Maintain regulator maintenance on the equipment at least every 3 years. Report should be monitored noting any degradation in equipment operation.
ELEVATOR	
42	Monitor room operating temperatures to ensure room remain at or lower than 24˚C.
MISCELLANEOUS ELECTRICAL	
43	Monitor pole condition and have a structural engineering provide schedule for replacement.

Appendix B: Climate Parameters

Legend	
Y	Yes
N	No
+	More
0	Same
-	Less
L	Low
M	Medium
H	High
NA	Not Applicable

Climate Parameters	Indicator	Definition	Unit	Threshold Value	Code Value	Past Modeled Value	Modeled Value (2050)	Modeled Range (2050)	Rel Future Value (2050)	Rel Future Value Range (2050)	Will Change over Time Horizon?	Will Threshold be triggered?	Impact of change in magnitude of climate event to threshold	Impact of change in frequency of climate event to threshold	How robust are climate projection results	**Probability of Occurrence Score**	Notes
						50%	50%	10th% - 90th%	50%	10th% - 90th%							
Contaminated water	Turbidity	Degree of particulate suspension in the water as an indicator for filtration requirements	Qualitative	<= 5 NTU	-	-	-	-	-	-	Y	+	L	NA	L	**1**	
	BOD	Biologically available oxygen demand as an indicator to the quality of water	Qualitative	E.Coli - None detectable	-	-	-	-	-	-	Y	+	L	NA	L	**1**	
				Coliform - Sample >10/100mL	-	-	-	-	-	-	Y	+	L	NA	L	**1**	
Heat waves	SU25	Number of summer days greater than 25°C as an indication of the change in duration of summer heat events (Climdex)	# Days	-	-	21	+35	-	56	40 : 70	Y	+	L	L	M	**7**	
	RP20 tasmax	The 20 year return period for maximum daily temperature as indication of change in peak summer heat events (Climdex)	°C	-	-	33.7	+4.4	-	38.1	36.5 : 39.6	Y	+	H	H	H	**7**	
	Cooling Dry Bulb 0.4%	Peak daily design temperature used for sizing cooling systems (ASHRAE)	°C	> 27°C	26.8	29.8	33.4	32:34.7	30.0	28.8 : 31.2	Y	+	H	H	H	**7**	
	WSDI	Warm spell duratoin index where the annual count of days with at least 6 consecutive days when the daily maximum temperature is greater than the 90th percentile	# Days	-	-	5	+64.9	-	69.9	22.3 : 116.7	Y	+	L	L	L	**7**	
Strong Winds	1/50 Wind Pressure	The 50 year return period for peak daily wind pressures (BCBC)	Pa	700	500	44.4	44.8	10.3:78.8	504.50	116 : 887.4	Y	0	L	L	L	**3**	
Storm Intensity and Frequency	R95P Total	Annual total precipitation when the daily rain amount (>1mm per day) consists of the 95th percentile	mm	-	-	229	+71	-	300	242 : 345	Y	+	H	M	M	**6**	
	R95P Day	Number of days where daily precipitation is greater than the 95th percentile for days with more than 1mm per day	# Days	-	-	8	+2	-	10	8 : 12	Y	0	M	M	M	**4**	
	RX1Day	Highest 1 day precipitation amount	mm	-	91	43	46	44:49	97.3	93.1 : 103.7	Y	+	M	L	M	**5**	
	1/5 Wind Driven Rain Pressure	Wind driven rain pressure 1/5 year return period (BCBC)	Pa	200	200	35.2	36.2	7.2:66.6	205.6818182	40.9 : 378.4	Y	0	L	L	L	**3**	Taken from 1/5 year return wind pressure

Legend	
Y	Yes
N	No
+	More
0	Same
-	Less
L	Low
M	Medium
H	High
NA	Not Applicable

Climate Parameters	Indicator	Definition	Unit	Threshold Value	Code Value	Past Modeled Value	Modeled Value (2050)	Modeled Range (2050)	Rel Future Value (2050)	Rel Future Value Range (2050)	Will Change over Time Horizon?	Will Threshold be triggered?	Impact of change in magnitude of climate event to threshold	Impact of change in frequency of climate event to threshold	How robust are climate projection results	**Probability of Occurrence Score**	Notes
						50%	50%	10th% - 90th%	50%	10th% - 90th%							
Warmer Winters	HDD18.0	Heating degree days base 18.3°C (ASHRAE) as general indicator of heating needs throughout the winter	°C-day	-	3000	2988	2156	1877:2456	2164.66	1884.5 : 2465.9	Y	-	L	L	H	**7**	
						3083.4	-833.3		2250.1	1953.9 : 2548.1	Y	-	L	L	H	**7**	RCP 4.5 and 8.5 Values from BCBC
Air Pollution (Forest Fires)	Seasonal Number	Number of regional fires (local impacts felt from lower mainland impacts)	Qualitative	-	-	-	-	-	-	-	Y	+	L	H	L	**5**	
Cold Snap	Heating Dry Bulb 1%	Peak daily design temperature used for sizing heating systems (ASHRAE)	°C	< -8°C	-8	-5.20	-1.50	-2.3:-.4	-2.31	-3.5 : -0.6	Y	-	H	H	H	**1**	
	ID	Icing days, representing the number of days where the peak temperature is below 0°C	# Days	-	-	2.80	-2	-	0.80	0.1 : 1.9	Y	-	L	L	H	**1**	
	CSDI	Cold spell duration index where the annual count of days at least 6 consecutive days where the daily maximum temperature is less than the 10th percentile	# Days	-	-	3.50	-2.8	-	0.70	-0.6 : 2	Y	-	L	L	H	**0**	
Winter Storm (Ice Storm)	Snow Load	The rain on snow load pressure, as defined by the BCBC	Pa	3.8 kPa	2.3	1	0.5	0.2:0.9	1.15	0.46 : 2.07	Y	-	H	L	L	2	
Humidity	Mean Coincident Wet Bulb 99%	The mean coincident wet bulb at the 99% sensible temperature	°C	> 19°C	17	21.9	25.2	23.4:26.7	19.56	18.2 : 20.7	Y	+	H	H	M	**7**	
Daily Temperature Range	DTR	Daily temperature range: monthly mean difference between the maximum and minimum daily temperature	°C	-	-	7.9	+0.1	-	8	7.5 : 8.4	Y	0	M	M	L	**3**	DTR only loosely correlated to the variable of interest (high swings in temperature within 24 hour period)
Drier and Warmer Summers	CDD18.3	Maximum length of dry spell where the maximum number of consecutive days with less than 1mm of rain.	°C	-	67	53	244	127:350	308	160.5 : 442.5	Y	+	H	H	H	**7**	ASHRAE ID 717720 for Entrance Island
	Summer Precipitation	Total summer precipitation	mm	-	-	98	80	59:99	-	-	Y		M	M	M	**5**	
Water Shortages	TXX-Annual	A high correlation between temperature and reservoir water shortages is assumed. TXX represents the monthly maximum value of daily maximum temperatures.	°C	-	-	30.6	34.2	33.0 : 35.0	34.2	33.0 : 35.0	Y	+	M	M	H	**6**	
Sea Level Rise	Sea Level Rise	Provincial mandated standard is approximately 1m/century	m	-	-	-	-	-	-	-	Y	+	NA	NA	NA	**7**	

Legend	
Y	Yes
N	No
+	More
0	Same
-	Less
L	Low
M	Medium
H	High
NA	Not Applicable

				Threshold Value	Code Value	Past Modeled Value	Modeled Value (2050)	Modeled Range (2050)	Rel Future Value (2050)	Rel Future Value Range (2050)	Will Change over Time Horizon?	Will Threshold be triggered?	Impact of change in magnitude of climate event to threshold	Impact of change in frequency of climate event to threshold	How robust are climate projection results	**Probability of Occurrence Score**	Notes
Climate Parameters	**Indicator**	**Definition**	**Unit**			50%	50%	10th% - 90th%	50%	10th% - 90th%							
Warmer Domestic Supply Water	Summer Temperature (TXX-Summer)	Average summer time temperature	°C	-	-	30.60	34.10	32.7 : 35	34.10	32.7 : 35	Y	+	M	M	M	**7**	
	Water Temperature	Required water temperature for back-up cooling	°C	> 10°C	-	-	-	-	-	-	Y	+	H	H	M	**6**	Already exceeded in 2016
Flooding	Rx1day	1 year maximum daily precipitation	mm	-	-	-	-	-	-	-	Y	+	M	M	M	**-**	
	RP20 PR	1 in 20 year 1 day rainfall	mm	-	-	-	-	-	-		Y	+	M	M	M	**-**	
		1 in 50 year 1 day rainfall	mm	-	91	66.4	85	72.8:97.9	116	99.8 : 134.2	Y	+	M	M	M	**2**	Past magnitude will definitely be exceeded, this score is for frequency of what currently is a 3 (1 in 10 year)
		1 in 10 year 15 minute rainfall	mm	-	10	-	-	-	-	-	Y	+	M	M	M	**4**	Past magnitude will definitely be exceeded, this score is for frequency of what currently is a 3 (1 in 10 year)
	Ponding	Ponding that impacts pedestrian and/or traffic flow	m	> 0.1	-	-	-	-	-	-	Y	+	M	M	M	**-**	

Appendix C: Probability, Severity, and Risk Scores

Appendix C - Probability, Severity, Risk Score

		1			2			3			6			7			9			12			14		
		Contaminated water			**Heat waves**			**Strong Winds**			**Air Pollution (Forest Fires)**			**Cold Snap**			**Humidity**			**Water Shortages**			**Warmer Domestic Supply Water**		
	Infrastructure Components	Turbidity Levels Greater than Capacity of Onsite Water Treatment			Cooling Dry Bulb exceeds existing CSA/BCBC Design of 27C			Wind Pressures Exceed Equipment Design			Forest Fire Occurrence			Temperature Falls Below Design Winter Temperature of -8C			Peak WB temperature exceeds BCBC July MCWB of 19C			water demand exceeds supply; correlation b/w temp and reservoir levels: TXX Annual = monthly max value of daily max temp, C			Water Temperature Exceeds Required Temperature for Back-up Cooling (>10C)		
		P	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**	**P**	**S**	**R**
M	**MECHANICAL**																								
	Thermal Plant																								
1	Gas supply		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
2	Boilers	1	6	6		-	-		-	-		-	-	1	1	1		-	-	6	6	36		-	-
3	Steam, water distribution		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
4	Back-up fuel		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
5	Pumps		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
6	Heat Exchangers		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
	Cooling Plant																								
7	Chillers		-	-	7	5	35		-	-		-	-		-	-	7	5	35		-	-		-	-
8	Chilled Water Pumps & Distribution		-	-	7	5	35		-	-		-	-		-	-	7	4	28		-	-		-	-
9	Cooling Towers		-	-	7	5	35		-	-		-	-		-	-	7	5	35	6	6	36		-	-
10	Condenser Water Pumps & Distribution		-	-	7	5	35		-	-		-	-		-	-	7	5	35		-	-		-	-
11	Back-up cooling water	1	2	2	7	6	42		-	-		-	-		-	-		-	-	6	4	24	6	4	24
	Critical Air Systems (OR, NICU, PAR, MDR)																								
12	O/A intakes		-	-		-	-		-	-	5	6	30		-	-		-	-		-	-		-	-
13	Fans		-	-	7	3	21		-	-		-	-		-	-	7	6	42		-	-		-	-
14	Cooling Coils		-	-	7	5	35		-	-		-	-		-	-	7	5	35		-	-		-	-
15	Heating Coils		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
16	Humidification	1	3	3		-	-		-	-		-	-	1	4	4		-	-		-	-		-	-
17	Air Distribution (Ductwork, dampers, etc.)		-	-	7	4	28		-	-		-	-		-	-	7	5	35		-	-		-	-
	Other Central Air Systems																								
18	O/A intakes		-	-		-	-		-	-	5	6	30		-	-		-	-		-	-		-	-
19	Fans		-	-	7	3	21		-	-		-	-		-	-	7	3	21		-	-		-	-

	Infrastructure Components	1			2			3			6			7			9			12			14		
		Contaminated water			Heat waves			Strong Winds			Air Pollution (Forest Fires)			Cold Snap			Humidity			Water Shortages			Warmer Domestic Supply Water		
		Turbidity Levels Greater than Capacity of Onsite Water Treatment			Cooling Dry Bulb exceeds existing CSA/BCBC Design of 27C			Wind Pressures Exceed Equipment Design			Forest Fire Occurrence			Temperature Falls Below Design Winter Temperature of -8C			Peak WB temperature exceeds BCBC July MCWB of 19C			water demand exceeds supply; correlation b/w temp and reservoir levels: TXX Annual = monthly max value of daily max temp, C			Water Temperature Exceeds Required Temperature for Back-up Cooling (>10C)		
20	Cooling Coils		-	-	7	4	28		-	-		-	-		-	-	7	5	35		-	-		-	-
21	Heating Coils		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
22	Humidification		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
23	Air Distribution (Ductwork, dampers, etc.)		-	-	7	3	21		-	-		-	-		-	-	7	3	21		-	-		-	-
	Unitary HVAC Systems																								
24	Rooftop Units		-	-	7	3	21	3	2	6	5	6	30		-	-	7	4	28		-	-		-	-
25	Split Systems		-	-	7	3	21		-	-		-	-		-	-		-	-		-	-		-	-
	Exhaust Systems																								
26	Exhaust Systems		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
27	Isolation Rooms		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
	Radiant Heating and Cooling Systems																								
28	Radiation and Panel Systems		-	-	7	2	14		-	-		-	-		-	-		-	-		-	-		-	-
	DDC System																								
29	Cooling Control Valves		-	-	7	2	14		-	-		-	-		-	-		-	-		-	-		-	-
	Food & Housekeeping Services																								
30	Refrigeration		-	-	7	3	21		-	-		-	-		-	-		-	-		-	-		-	-
	Medical Gasses																								
31	Oxygen (O2)		-	-		-	-		-	-		-	-		-	-	7	5	35		-	-		-	-
32	Medical Air		-	-		-	-		-	-	5	6	30		-	-	7	3	21		-	-		-	-
33	Medical Vacuum		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-
34	Other Medical Gases		-	-		-	-		-	-		-	-		-	-		-	-		-	-		-	-

	Infrastructure Components	2			3			4			8			9			15		
		Heat waves			Strong Winds			Storm Intensity and Frequency			Winter Storm (Ice Storm)			Humidity			Flooding		
		P	S	R	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
E	**ELECTRICAL**																		
	Electrical Distribution System																		
1	BC Hydro Supply		-	-	3	5	15	3	4	12	2	4	8		-	-		-	-
2	Main MV Distribution Equipment	7	1	7		-	-		-	-		-	-	7	2	14	4	1	4
3	Main Distribution Transformers	7	2	14		-	-		-	-		-	-		-	-	4	1	4
4	Secondary Distribution Equipment	7	1	7		-	-		-	-		-	-	7	2	14	4	1	4
5	Distribution Cabling	7	1	7		-	-		-	-		-	-		-	-		-	-
	Back-up Generators																		
6	Capacity		-	-		-	-		-	-		-	-		-	-		-	-
7	Location		-	-		-	-		-	-		-	-		-	-	4	1	4
8	Fuel oil storage and delivery system		-	-		-	-		-	-		-	-		-	-		-	-
9	Equipment Monthly / Yearly testing		-	-		-	-		-	-		-	-		-	-		-	-
10	Equipment Servicing		-	-		-	-		-	-		-	-		-	-		-	-
	Life Safety																		
11	Fire Alarm System		-	-		-	-		-	-		-	-		-	-		-	-
	Communications		-			-			-			-			-			-	
12	Site Service for Tele/Com		-	-		-	-		-	-		-	-		-	-		-	-
13	Sever Room Equipment		-	-		-	-		-	-		-	-		-	-		-	-
14	UPS System	7	1	7		-	-		-	-		-	-		-	-		-	-
15	Data cabling Network		-	-		-	-		-	-		-	-		-	-		-	-
16	Nurse Call	7	1	7		-	-		-	-		-	-		-	-		-	-
17	Security Systems (cameras, access card, CCT)	7	1	7		-	-		-	-		-	-		-	-		-	-
	Elevators																		
18	Elevator Controllers	7	3	21		-	-		-	-		-	-		-	-		-	-
	Misc Elect Systems																		
19	Lighting - Interior		-	-		-	-		-	-		-	-		-	-		-	-
20	Lighting - Exterior		-	-	3	3	9	3	3	9	2	3	6	7	2	14		-	-

	Infrastructure Components	3 Strong Winds 0.7 kPa or 122kph			4 Storm Intensity and Frequency 275 mm			7 Cold Snap 5 Icing Degree Days			8 Winter Storm (Ice Storm) 3.8 kPa			15 Flooding		
		P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
S	**STRUCTURE**															
	Superstructure - Primary															
1	Steel Frames	3	1	3	3	6	18		-	-	2	6	12		-	-
2	Concrete Structures	3	1	3	3	6	18	1	2	2	2	6	12		-	-
3	Foundation		-	-		-	-		-	-		-	-	4	4	16
4	Slabs		-	-		-	-		-	-		-	-	4	4	16
5	Wood	3	5	15	3	6	18		-	-	2	6	12		-	-
6	Suspended Floors		-	-		-	-		-	-		-	-		-	-
	Superstructure - Secondary															
7	Awnings	3	2	6		-	-		-	-	2	4	8		-	-
8	Steel Structures	3	2	6		-	-		-	-	2	3	6		-	-
9	Concrete Overhangs	3	1	3		-	-	1	3	3	2	4	8		-	-
10	Exterior Attachments	3	2	6		-	-		-	-	2	2	4		-	-
11	In-fill Walls	3	4	12		-	-		-	-		-	-		-	-
12	Guards	3	2	6		-	-		-	-		-	-		-	-
13	Stairs		-	-		-	-		-	-	2	3	6		-	-
14	Ramps		-	-		-	-		-	-	2	3	6		-	-

	Infrastructure Components	2			3			4			6		
		Heat waves			Strong Winds			Storm Intensity and Frequency			Air Pollution (Forest Fires)		
		33.7°C			0.7 kPa			200 Pa			Qualitative		
		P	S	R	P	S	R	P	S	R	P	S	R
EN	**ENCLOSURE**												
	Fenestration												
1	Curtain walls	7	2	14	3	3	9	3	4	12	5	2	10
2	Punch windows	7	2	14	3	4	12	3	4	12	5	2	10
3	Window wall	7	2	14	3	3	9	3	4	12	5	2	10
4	Sliding doors	7	3	21	3	4	12	3	2	6	5	2	10
5	Swing doors		-	-	3	3	9	3	2	6	5	2	10
6	Overhead doors		-	-	3	1	3	3	2	6		-	-
7	Skylights	7	2	14	3	4	12	3	3	9	5	2	10
8	Sun control		-	-	3	2	6		-	-	5	2	10
	Insulation												
9	Roof insulation		-	-	3	2	6		-	-		-	-
10	Wall insulation		-	-		-	-		-	-		-	-
	Waterproofing												
11	Sealants	7	2	14	3	2	6	3	3	9		-	-
12	Flashing		-	-	3	2	6	3	4	12	5	2	10
13	Cladding		-	-	3	3	9	3	2	6	5	2	10
14	Coatings		-	-		-	-	3	2	6	5	2	10
15	Roof Membrane	7	3	21	3	5	15	3	4	12		-	-

	Infrastructure Components	2			3			4			6		
		Heat waves			Strong Winds			Storm Intensity and Frequency			Air Pollution (Forest Fires)		
		33.7°C			0.7 kPa			200 Pa			Qualitative		
	Penetrations												
16	Mechanical Penetrations - Walls		-	-		-	-	3	2	6		-	-
17	Mechanical Penetrations - Roof		-	-		-	-	3	2	6		-	-
	Vapour/Air Barriers												
18	Walls		-	-	3	2	6		-	-		-	-
19	Roof		-	-	3	2	6		-	-		-	-
20	Foundation		-	-		-	-		-	-		-	-
	Finishes												
21	Paint	7	2	14		-	-		-	-	5	2	10
22	Interior finishes		-	-		-	-		-	-	5	2	10
	Miscellaneous												
23	Chemical Storage/Hazardous Materials		-	-		-	-		-	-		-	-

	Infrastructure Components	1			2			3			4			5			7		
		Contaminated water			**Heat waves**			**Strong Winds**			**Storm Intensity and Frequency**			**Warmer Winters**			**Cold Snap**		
		Turbidity/BOD above level that can be treated at municipal level (or current on-site treatment capability)			Cooling Dry Bulb exceeds existing CSA/BCBC Design of 27C (Prism); SU25 - # of summer days > 25 C; WSDI - warm spell duration index			0.7 kPa or 122kph			275 mm			HDD18.3			5 Icing Degree Days (ID); Temperature Falls Below Design Winter Temperature of -8C		
		P		R	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
W	**WATER**																		
	Domestic Water System																		
1	Delivery, storage, distribution system (city supply is pumped, not gravity fed)	1	2	2		-	-		-	-		-	-		-	-	1	6	6
2	Water treatment/quality (assuming there is not currently on-site treatment except for R/O water)	1	4	4		-	-		-	-	3	2	6	7	-	-		-	-
3	Quantity		-	-	7	-	-		-	-		-	-	7	-	-	1	-	-
4	Quality		-	-		-	-		-	-	3	-	-	7	-	-		-	-
5	Back-up water supply (2 feeds, either of which can supply the loop. Emergency potable supply from fire hydrants - no on-site storage - have 3" dia flexible water lines)	1	4	4		-	-		-	-	3	2	6		-	-	1	2	2
6	Process water supply (central sterile, kitchen)	1	4	4		-	-		-	-	3	2	6		-	-	1	2	2
7	RO Water (for labs, renal, MDRD) - on emergency power - electricity needed to generate pressure	1	5	5		-	-		-	-	3	2	6		-	-	1	6	6
8	Drinking water supply	1	5	5		-	-		-	-	3	6	18		-	-	1	6	6
9	Plumbing fixture supply (toilets, showers, lavs, Operating Room sinks)	1	6	6		-	-		-	-	3	6	18		-	-	1	6	6
	HVAC Systems																		
10	Thermal plant make-up water	1	-	N/A		-	-		-	-		-	-		-	-		-	-
11	Cooling tower makeup water	1	-	N/A	7	-	-	3	4	12		-	-	7	1	7	1	1	1
	Storm Water Management System																		
12	Roof drains		-	-		-	-	3	-	-	3	5	15		-	-	1	6	6
13	Ground level storm water drainage (piped)		-	-		-	-		-	-	3	5	15		-	-	1	2	2
14	Permeable cover, bioswales (infiltration based)		-	-		-	-		-	-	3	5	15		-	-	1	2	2

	Infrastructure Components	8			9			11			12			15		
		Winter Storm (Ice Storm)			**Humidity**			**Dryer and Warmer Summers**			**Water Shortages**			**Flooding**		
		3.8 kPa			Peak WB temperature exceeds BCBC July MCWB of 19C			Total summer precipitation, mm; CDD: max # of consecutive days with less than 1mm rain			water demand exceeds supply; correlation b/w temp and reservoir levels: TXX Annual = monthly max value of daily max temp, C			1 in 2 yr, 50 yr, 100 yr max daily precipitation, mm		
		P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
W	**WATER**															
	Domestic Water System															
1	Delivery, storage, distribution system (city supply is pumped, not gravity fed)		-	-		-	-		-	-		-	-		-	-
2	Water treatment/quality (assuming there is not currently on-site treatment except for R/O water)		-	-		-	-		-	-		-	-		-	-
3	Quantity		-	-		-	-	7	-	-	6	4	24		-	-
4	Quality		-	-		-	-		-	-		-	-	4	-	-
5	Back-up water supply (2 feeds, either of which can supply the loop. Emergency potable supply from fire hydrants - no on-site storage - have 3" dia flexible water lines)		-	-		-	-	7	2	14	6	4	24	4	2	8
6	Process water supply (central sterile, kitchen)		-	-		-	-	7	2	14	6	5	30	4	2	8
7	RO Water (for labs, renal, MDRD) - on emergency power - electricity needed to generate pressure		-	-		-	-	7	5	35	6	5	30	4	2	8
8	Drinking water supply		-	-		-	-	7	5	35	6	5	30	4	6	24
9	Plumbing fixture supply (toilets, showers, lavs, Operating Room sinks)		-	-		-	-	7	5	35	6	5	30	4	6	24
	HVAC Systems															
10	Thermal plant make-up water		-	-		-	-		-	-		-	-		-	-
11	Cooling tower makeup water		-	-	7	4	28	7	4	28	6	5	30		-	-
	Storm Water Management System															
12	Roof drains	2	7	14		-	-		-	-		-	-	4	5	20
13	Ground level storm water drainage (piped)	2	6	12		-	-		-	-		-	-	4	5	20
14	Permeable cover, bioswales (infiltration based)	2	6	12		-	-		-	-		-	-	4	5	20

	Infrastructure Components	1			2			3			4			6		
		Contaminated water			Heat waves			Strong Winds			Storm Intensity and Frequency			Air Pollution (Forest Fires)		
		Turbidity <= 5 NTU E.Coli - None Detectable Coliform - No sample >10/100mL			6 consecutive days when the daily maximum temperature is greater than the 90th percentile			The 50 year return period for peak daily wind pressures			Annual total precipitation when the daily rain amount (>1mm per day) consists of the 95th percentile. Number of days where			Varies		
		P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
C	**CIVIL**															
1	Fire Supression System (i.e. fire hydrants)	1	1	1		-	-		-	-		-	-		-	-
	Site Access Systems															
2	Roads/Parking Areas		-	-		-	-		-	-	3	2	6		-	-
3	Pedestrian		-	-		-	-		-	-	3	2	6		-	-
4	Helipad		-	-		-	-		-	-	3	2	6	5	1	5
5	Loading docks		-	-		-	-		-	-	3	4	12		-	-
	Waste storage & removal															
6	Bio-waste		-	-		-	-		-	-		-	-		-	-
7	Kitchen	1	5	5		-	-		-	-		-	-		-	-
8	General waste		-	-		-	-		-	-		-	-		-	-
	Sanitary Sewer															
9	Acid neutralizer		-	-		-	-		-	-		-	-		-	-
10	Grease interceptors		-	-		-	-		-	-		-	-		-	-
	Landscaping															
11	Trees/irrigation/grass/vegetation	1	0	0	7	3	21	3	4	12	3	2	6	5	1	5
12	Retaining walls		-	-		-	-		-	-	3	3	9		-	-
13	Drainage infrastucture - grading and drains		-	-		-	-		-	-	3	2	6		-	-
14	Water supply - con. Reservoir		-	-		-	-		-	-	3	3	9	5	0	0
15	Signage		-	-		-	-	3	3	9		-	-		-	-

	Infrastructure Components	7 Cold Snap			8 Winter Storm (Ice Storm)			9 Humidity			10 Daily Temperature Range			11 Dryer and Warmer Summers			12 Water Shortages			15 Flooding		
		Cold spell duration index where the annual count of days at least 6 consecutive days where the daily maximum temperature is less than the 10th percentile.			The rain on snow load pressure			The mean coincident wet bulb at the 99% sensible temperature			Varies			Maximum length of dry spell where the maximum number of consecutive days with less than 1mm of rain.			A high correlation between temperature and reservoir water shortages is assumed.			Ponding That Impacts Pedestrian and/or Traffic Flow >0.1m depth		
		P	S	R	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
C	**CIVIL**																					
1	Fire Supression System (i.e. fire hydrants)	1	0	0	2	3	6	7	1	7	3	0	0		-	-		-	-		-	-
	Site Access Systems																					
2	Roads/Parking Areas	1	3	3	2	4	8		-	-		-	-		-	-		-	-	4	3	12
3	Pedestrian	1	3	3	2	4	8		-	-		-	-		-	-		-	-		-	-
4	Helipad	1	3	3	2	5	10	7	1	7		-	-		-	-		-	-		-	-
5	Loading docks	1	1	1	2	3	6	7	1	7		-	-		-	-		-	-	4	3	12
	Waste storage & removal																					
6	Bio-waste		-	-		-	-		-	-		-	-		-	-		-	-		-	-
7	Kitchen		-	-		-	-		-	-		-	-		-	-		-	-		-	-
8	General waste		-	-		-	-		-	-		-	-		-	-		-	-		-	-
	Sanitary Sewer																					
9	Acid neutralizer		-	-		-	-		-	-		-	-		-	-		-	-		-	-
10	Grease interceptors		-	-		-	-		-	-		-	-		-	-		-	-		-	-
	Landscaping																					
11	Trees/irrigation/grass/vegetation	1	1	1	2	2	4		-	-	3	0	0	7	2	14	6	3	18	4	2	8
12	Retaining walls		-	-		-	-	7	1	7		-	-		-	-		-	-	4	4	20
13	Drainage infrastucture - grading and drains		-	-		-	-		-	-		-	-		-	-		-	-	4	2	8
14	Water supply - con. Reservoir		-	-		-	-		-	-		-	-	7	1	7		-	-		-	-
15	Signage		-	-		-	-		-	-		-	-		-	-		-	-		-	-

Appendix D: Risk Score Summary

Appendix D - Risk Score Summary

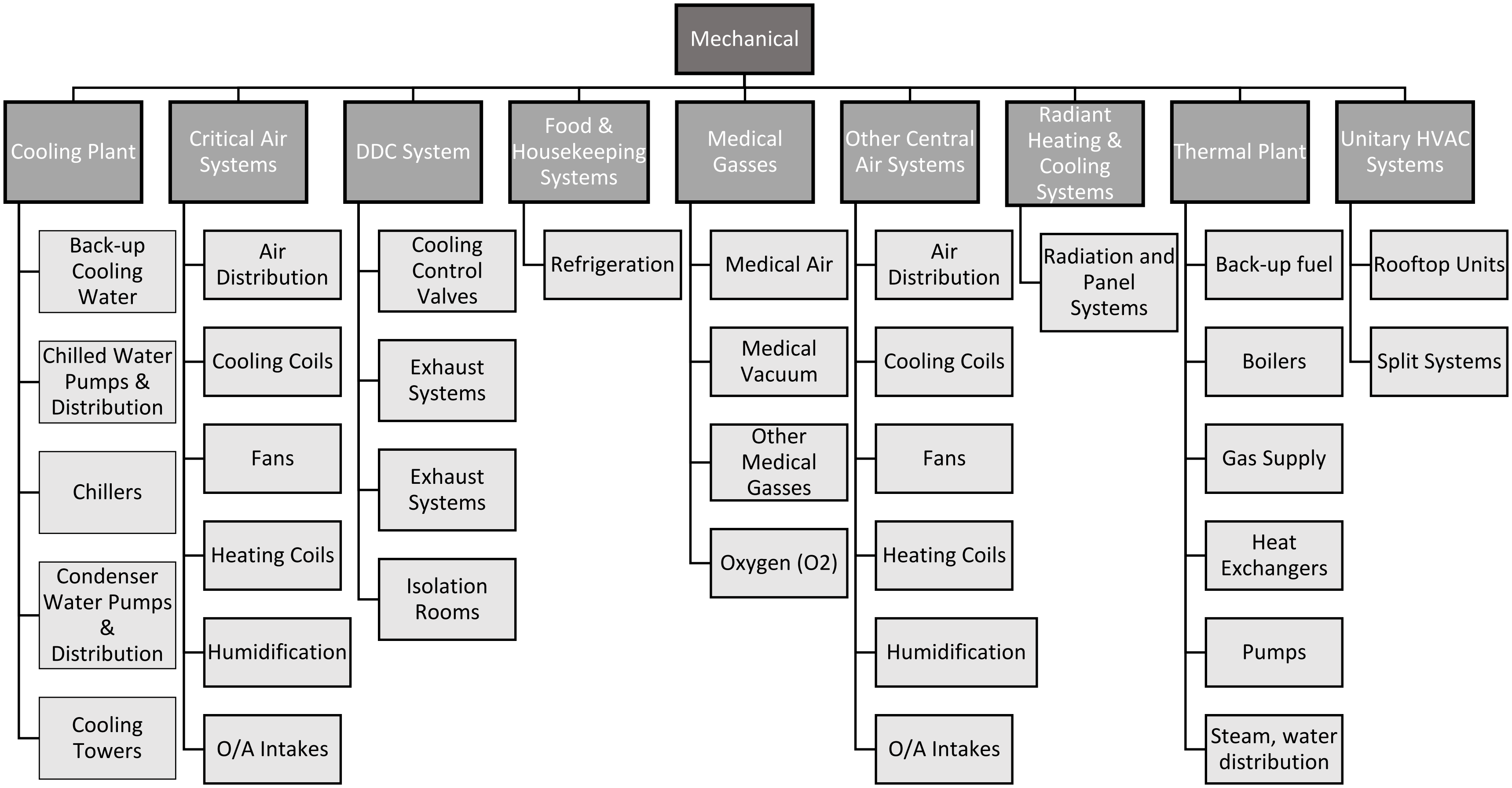
Low Risk	Medium Risk	High Risk

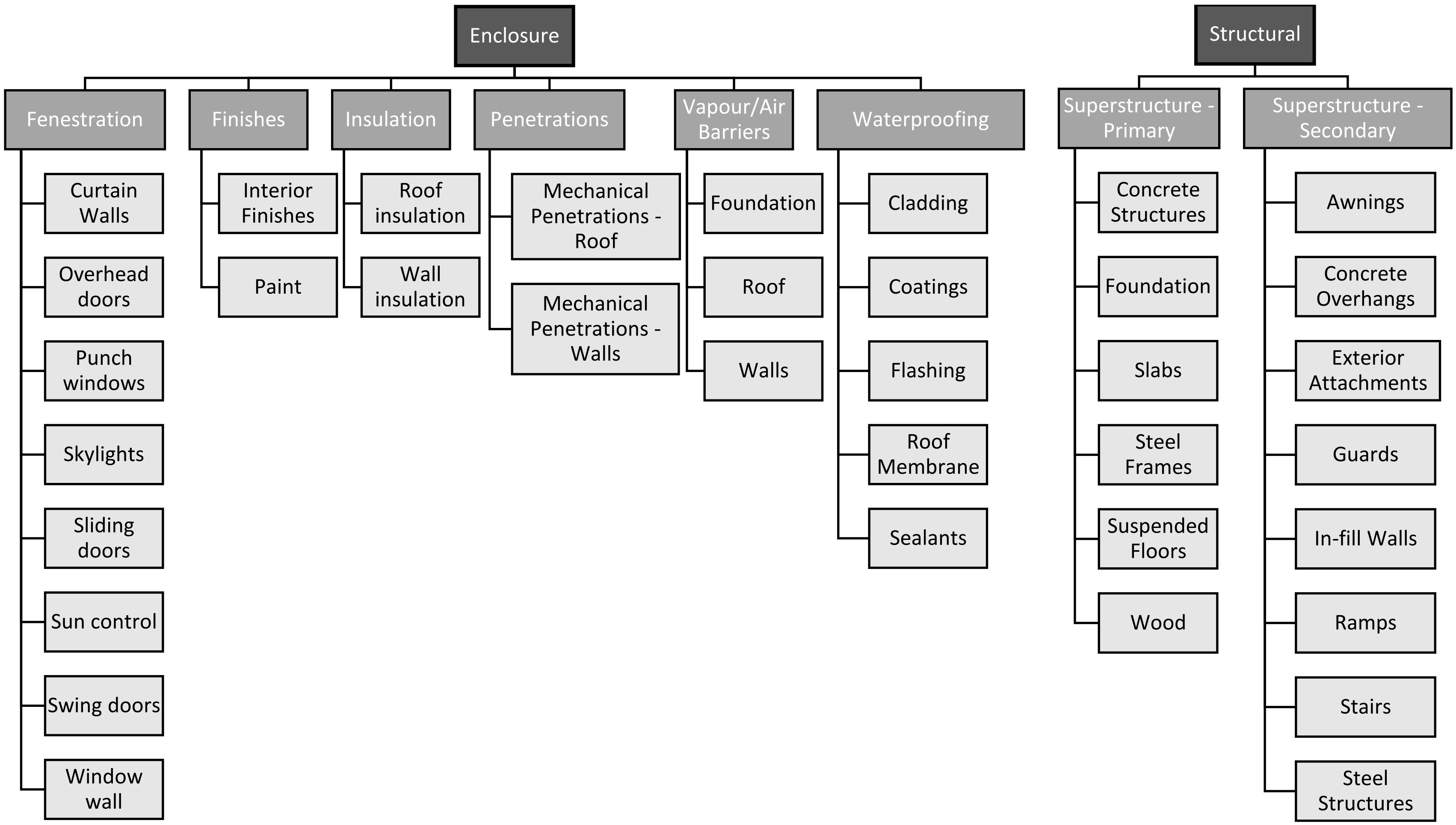
Division	Category	Infrastructure Component	Highest Risk Score	Highest Risk (Low, Special Case, Medium, High)	Priority	Climate Parameter and Risk Score 1 Contaminated Water	2 Heat Waves	3 Strong Winds	4 Storm Intensity and Frequency	5 Warmer Winters	6 Air Pollution (Forest Fires)	7 Cold Snap	8 Winter Storm (Ice Storm)	9 Humidity	10 Daily Temperature Range	11 Dryer and Warmer Summers	12 Water Shortages	13 Sea Level Rise	14 Warmer Domestic Supply Water	15 Flooding
Civil	Landscaping	Drainage infrastructure - grading and	8	Medium	21 to 40 Years				6											8
Civil	Landscaping	Retaining walls	20	Medium	11 to 20 Years				9					7						20
Civil	Civil	Fire Supression System (i.e. fire	7	Special Case	Within 10yrs	1						0	6	7	0					
Civil	Landscaping	Signage	9	Medium	Immediately			9												
Civil	Landscaping	Trees/irrigation/grass/vegetation	21	Medium	Within 10yrs	0	21	12	6		5	1	4		0	14	18			8
Civil	Landscaping	Water supply - con. Reservoir	9	Medium					9		0					7				
Civil	Sanitary Sewer	Acid neutralizer	0	Low																
Civil	Sanitary Sewer	Grease interceptors	0	Low																
Civil	Site Access Systems	Helipad	10	Medium					6		5	3	10	7						
Civil	Site Access Systems	Loading docks	12	Medium					12			1	6	7						12
Civil	Site Access Systems	Pedestrian	8	Medium	Within 10yrs				6			3	8							
Civil	Site Access Systems	Roads/Parking Areas	12	Medium					6			3	8							12
Civil	Waste storage & removal	Bio-waste	0	Low																
Civil	Waste storage & removal	General Waste	0	Low																
Civil	Waste storage & removal	Kitchen	5	Low		5														
Electrical	Back-up Generators	Capacity	0	Low																
Electrical	Back-up Generators	Equipment Monthly / Yearly testing	0	Low																
Electrical	Back-up Generators	Equipment Servicing	0	Low																
Electrical	Back-up Generators	Fuel oil storage and delivery system	0	Low																
Electrical	Back-up Generators	Location	4	Low																4
Electrical	Communications	Data cabling Network	0	Low	Immediately															
Electrical	Communications	Nurse Call	7	Special Case	Immediately		7													
Electrical	Communications	Security Systems (cameras, access	7	Special Case	Within 10yrs		7													
Electrical	Communications	Server Room Equipment	0	Low																
Electrical	Communications	Site Service for Tele/Com	0	Low																
Electrical	Communications	UPS System	7	Special Case	Within 10yrs		7													
Electrical	Electrical Distribution System	BC Hydro Supply	15	Medium				15	12				8							
Electrical	Electrical Distribution System	Distribution Cabling	7	Special Case			7													
Electrical	Electrical Distribution System	Main Distribution Transformers	14	Medium	Within 10yrs		14													4
Electrical	Electrical Distribution System	Main MV Distribution Equipment	14	Medium			7							14						4
Electrical	Electrical Distribution System	Secondary Distribution Equipment	14	Medium			7							14						4
Electrical	Life Safety	Fire Alarm System	0	Low	Within 10yrs															
Electrical	Misc Elect Systems	Lighting - Exterior	14	Medium	Immediately			9	9				6	14						
Electrical	Misc Elect Systems	Lighting - Interior	0	Low	Immediately															
Enclosure	Fenestration	Curtain walls	14	Medium			14	9	12		10									
Enclosure	Fenestration	Overhead doors	6	Low	Within 10yrs			3	6											

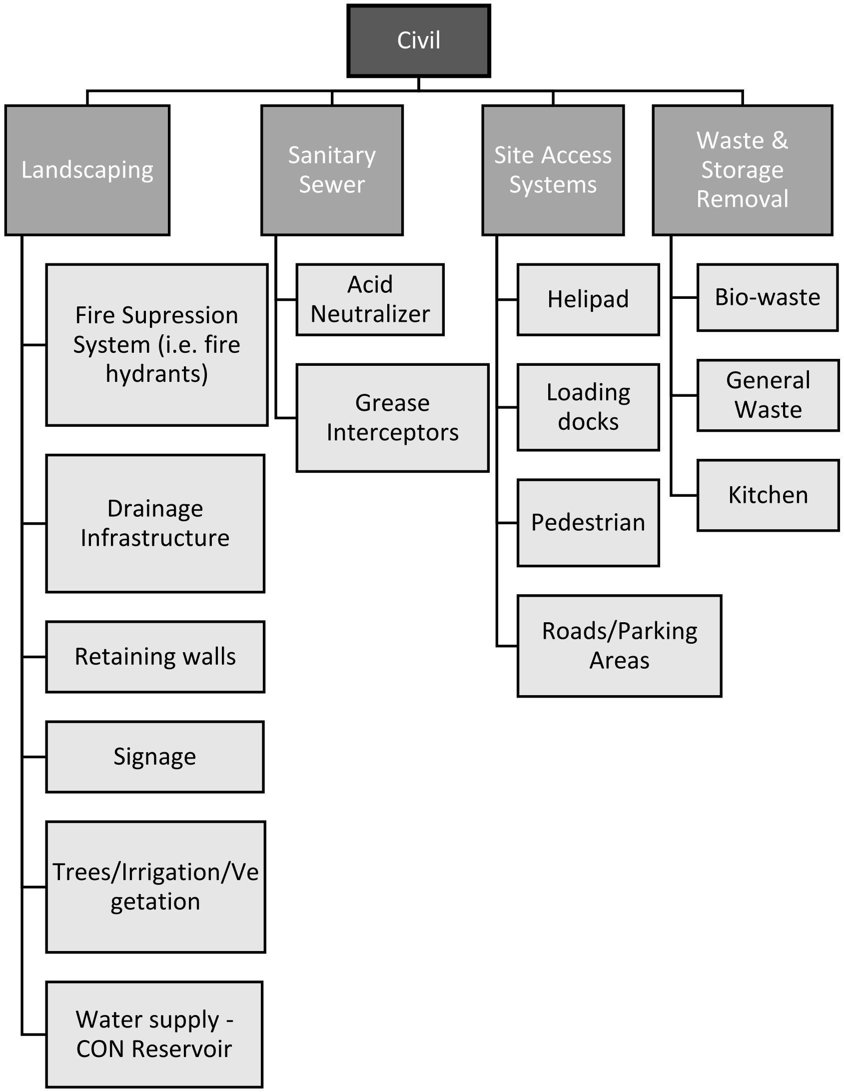
Low Risk	Medium Risk	High Risk

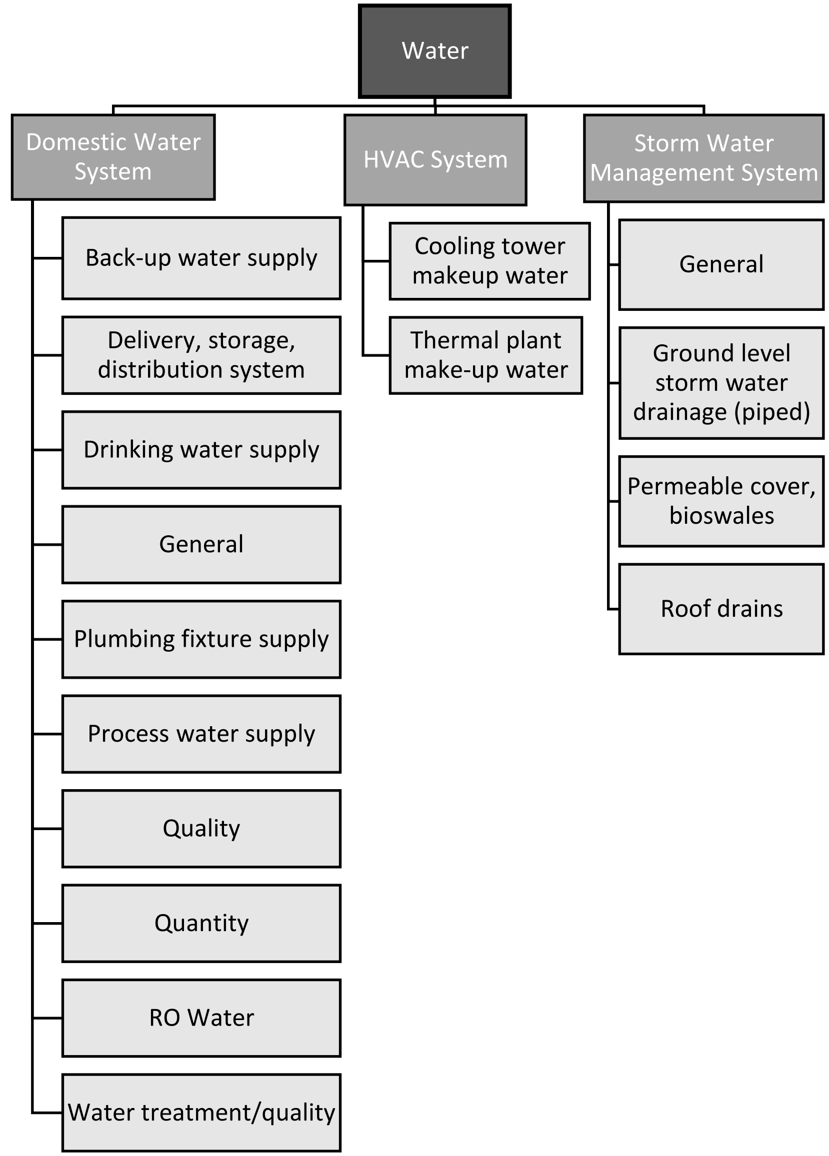
Division	Category	Infrastructure Component	Highest Risk Score	Highest Risk (Low, Special Case, Medium, High)	Priority	Climate Parameter and Risk Score 1 Contaminated Water	2 Heat Waves	3 Strong Winds	4 Storm Intensity and Frequency	5 Warmer Winters	6 Air Pollution (Forest Fires)	7 Cold Snap	8 Winter Storm (Ice Storm)	9 Humidity	10 Daily Temperature Range	11 Dryer and Warmer Summers	12 Water Shortages	13 Sea Level Rise	14 Warmer Domestic Supply Water	15 Flooding
Enclosure	Fenestration	Punch windows	14	Medium	Within 10yrs		14	12	12		10									
Enclosure	Fenestration	Skylights	14	Medium	Within 10yrs		14	12	9		10		8							
Enclosure	Fenestration	Sliding doors	21	Medium			21	12	6		10									
Enclosure	Fenestration	Swing doors	10	Medium	Within 10yrs			9	6		10									
Enclosure	Fenestration	Window wall	14	Medium			14	9	12		10									
Enclosure	Finishes	Interior Finishes	10	Medium	Within 10yrs						10									
Enclosure	Finishes	Paint	14	Medium	Within 10yrs		14				10				3	7				
Enclosure	Insulation	Roof insulation	6	Low				6												
Enclosure	Insulation	Wall insulation	0	Low																
Enclosure	Miscellaneous	Chemical Storage/Hazardous Materials	0	Low																
Enclosure	Penetrations	Mechanical Penetrations - Roof	6	Low					6											
Enclosure	Penetrations	Mechanical Penetrations - Walls	6	Low					6											
Enclosure	Vapour/Air Barriers	Foundation	0	Low																
Enclosure	Vapour/Air Barriers	Roof	6	Low				6												
Enclosure	Vapour/Air Barriers	Walls	7	Special Case				6						7						
Enclosure	Waterproofing	Coatings	10	Medium					6		10				3	7				
Enclosure	Waterproofing	Flashing	12	Medium				6	12		10									
Enclosure	Waterproofing	Roof Membrane	21	Medium	Immediately		21	15	12						6	14				
Enclosure	Waterproofing	Sealants	14	Medium	Immediately		14	6	9						6	7				
Mechanical	Cooling Plant	Back-up cooling water	42	High	Within 10yrs		42										24		24	
Mechanical	Cooling Plant	Chilled Water Pumps & Distribution	35	Medium	Within 10yrs		35							28						
Mechanical	Cooling Plant	Chillers	35	Medium	Within 10yrs		35							35						
Mechanical	Cooling Plant	Condenser Water Pumps &	35	Medium			35							35						
Mechanical	Cooling Plant	Cooling Towers	36	Medium	Immediately		35							35			36			
Mechanical	Critical Air Systems (OR, NICU, PAR, MDR)	Cooling Coils	35	Medium	Within 10yrs		35							35						
Mechanical	Critical Air Systems (OR, NICU, PAR, MDR)	Fans	42	High	Within 10yrs		21							42						
Mechanical	Critical Air Systems (OR, NICU, PAR, MDR)	Heating Coils	0	Low	Within 10yrs															
Mechanical	Critical Air Systems (OR, NICU, PAR, MDR)	O/A Intakes	30	Medium							30									
Mechanical	DDC System	Cooling Control Valves	14	Medium	Immediately		14													
Mechanical	Exhaust Systems	Exhaust Systems	0	Low	Within 10yrs															
Mechanical	Exhaust Systems	Isolation Rooms	0	Low																
Mechanical	Food & Housekeeping Services	Refridgeration	21	Medium			21													
Mechanical	Medical Gasses	Medical Air	35	Medium							30			35						
Mechanical	Medical Gasses	Medical Vacuum	0	Low	Immediately															
Mechanical	Medical Gasses	Oxygen (O2)	0	Low																
Mechanical	Other Central Air Systems	Cooling Coils	35	Medium	Within 10yrs		28							35						

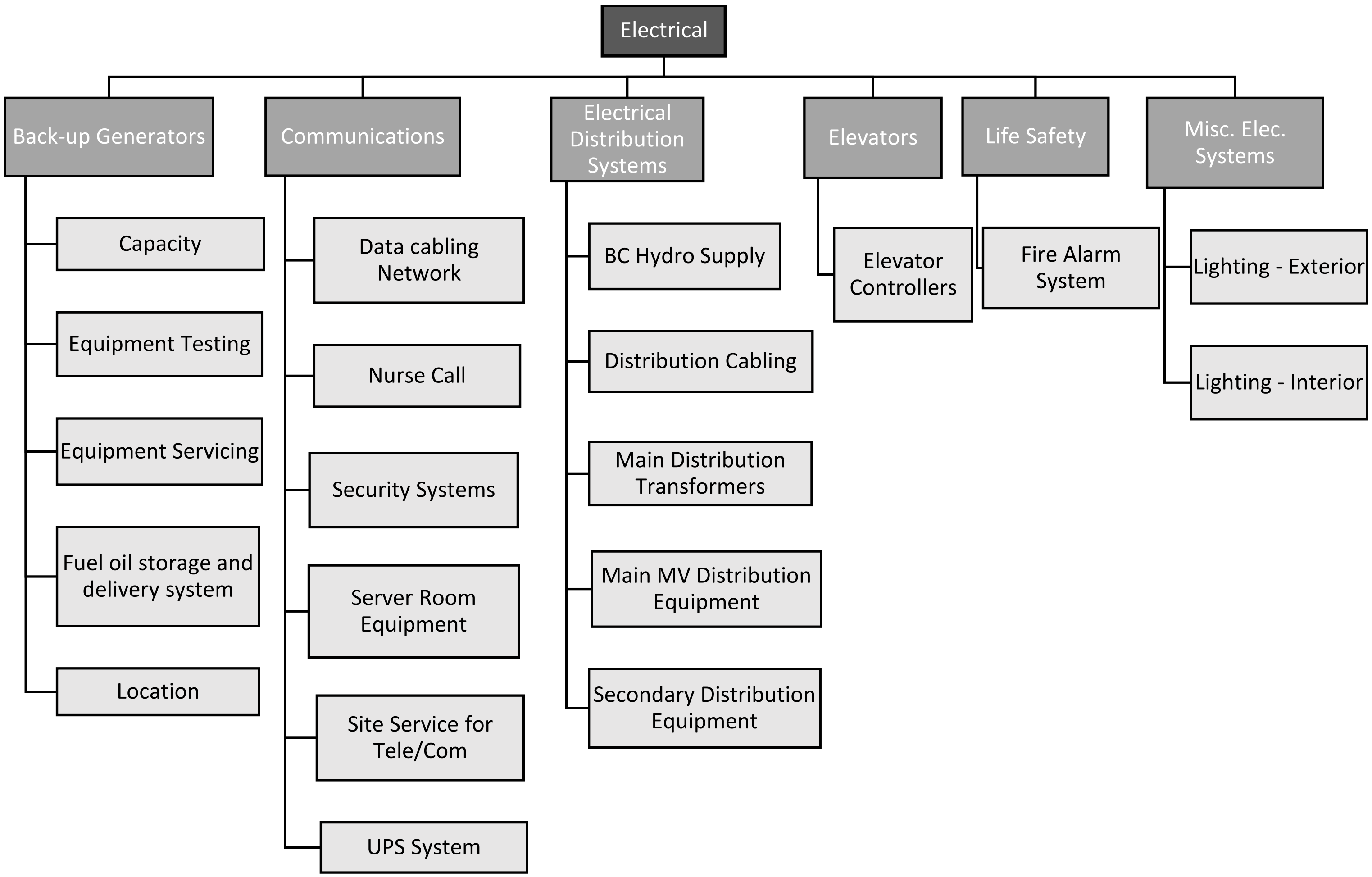
Appendix E: Summary of Infrastructure Components


Mechanical
Cooling Plant
Back-up Cooling Water
Chilled Water Pumps & Distribution
Chillers
Condenser Water Pumps & Distribution
Cooling Towers
Critical Air Systems
Air Distribution
Cooling Coils
Fans
Heating Coils
Humidification
O/A Intakes
DDC System
Cooling Control Valves
Exhaust Systems
Exhaust Systems
Isolation Rooms
Food & Housekeeping Systems
Refrigeration
Medical Gasses
Medical Air
Medical Vacuum
Other Medical Gasses
Oxygen (O2)
Other Central Air Systems
Air Distribution
Cooling Coils
Fans
Heating Coils
Humidification
O/A Intakes
Radiant Heating & Cooling Systems
Radiation and Panel Systems
Thermal Plant
Back-up fuel
Boilers
Gas Supply
Heat Exchangers
Pumps
Steam, water distribution
Unitary HVAC Systems
Rooftop Units
Split Systems


Enclosure
Fenestration
Curtain Walls
Overhead doors
Punch windows
Skylights
Sliding doors
Sun control
Swing doors
Window wall
Finishes
Interior Finishes
Paint
Insulation
Roof insulation
Wall insulation
Penetrations
Mechanical Penetrations - Roof
Mechanical Penetrations - Walls
Vapour/Air Barriers
Foundation
Roof
Walls
Waterproofing
Cladding
Coatings
Flashing
Roof Membrane
Sealants
Structural
Superstructure - Primary
Concrete Structures
Foundation
Slabs
Steel Frames
Suspended Floors
Wood
Superstructure - Secondary
Awnings
Concrete Overhangs
Exterior Attachments
Guards
In-fill Walls
Ramps
Stairs
Steel Structures


Civil
Landscaping
Fire Supression System (i.e. fire hydrants)
Drainage Infrastructure
Retaining walls
Signage
Trees/Irrigation/Vegetation
Water supply - CON Reservoir
Sanitary Sewer
Acid Neutralizer
Grease Interceptors
Site Access Systems
Helipad
Loading docks
Pedestrian
Roads/Parking Areas
Waste & Storage Removal
Bio-waste
General Waste
Kitchen


Water
Domestic Water System
Back-up water supply
Delivery, storage, distribution system
Drinking water supply
General
Plumbing fixture supply
Process water supply
Quality
Quantity
RO Water
Water treatment/quality
HVAC System
Cooling tower makeup water
Thermal plant make-up water
Storm Water Management System
General
Ground level storm water drainage (piped)
Permeable cover, bioswales
Roof drains



Electrical
Back-up Generators
Capacity
Equipment Testing
Equipment Servicing
Fuel oil storage and delivery system
Location
Communications
Data cabling Network
Nurse Call
Security Systems
Server Room Equipment
Site Service for Tele/Com
UPS System
Electrical Distribution Systems
BC Hydro Supply
Distribution Cabling
Main Distribution Transformers
Main MV Distribution Equipment
Secondary Distribution Equipment
Elevators
Elevator Controllers
Life Safety
Fire Alarm System
Misc. Elec. Systems
Lighting - Exterior
Lighting - Interior

Low Risk | Medium Risk | High Risk

Division	Category	Infrastructure Component	Highest Risk Score	Highest Risk (Low, Special Case, Medium, High)	Priority	Climate Parameter and Risk Score														
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
						Contaminated Water	Heat Waves	Strong Winds	Storm Intensity and Frequency	Warmer Winters	Air Pollution (Forest Fires)	Cold Snap	Winter Storm (Ice Storm)	Humidity	Daily Temperature Range	Dryer and Warmer Summers	Water Shortages	Sea Level Rise	Warmer Domestic Supply Water	Flooding
Mechanical	Other Central Air Systems	Fans	21	Medium	Within 10yrs		21							21						
Mechanical	Other Central Air Systems	Heating Coils	0	Low	Within 10yrs															
Mechanical	Other Central Air Systems	O/A Intakes	30	Medium							30									
Mechanical	Thermal Plant	Back-up fuel	0	Low																
Mechanical	Thermal Plant	Boilers	36	Medium		6											36			
Mechanical	Thermal Plant	Gas Supply	0	Low																
Mechanical	Thermal Plant	Heat Exchangers	0	Low	Immediately															
Mechanical	Thermal Plant	Pumps	0	Low	Within 10yrs															
Mechanical	Thermal Plant	Steam, water distribution	0	Low																
Mechanical	Unitary HVAC Systems	Split Systems	21	Medium	Immediately		21													
Structural	Superstructure - Primary	Concrete Structures	18	Medium	Within 10yrs			3	18			2	12							
Structural	Superstructure - Primary	Slabs	16	Medium																16
Structural	Superstructure - Primary	Steel Frames	18	Medium				3	18				12							
Structural	Superstructure - Primary	Wood	18	Medium				15	18				12							
Structural	Superstructure - Secondary	Awnings	8	Medium				6					8							
Structural	Superstructure - Secondary	Concrete Overhangs	8	Medium				3				3	8							
Structural	Superstructure - Secondary	Exterior Attachments	6	Low				6					4							
Structural	Superstructure - Secondary	Guards	6	Low	Immediately			6												
Structural	Superstructure - Secondary	In-fill Walls	12	Medium				12												
Structural	Superstructure - Secondary	Ramps	6	Low	Within 10yrs								6							
Structural	Superstructure - Secondary	Stairs	6	Low	Within 10yrs								6							
Structural	Superstructure - Secondary	Steel Structures	6	Low				6					6							
Water	Domestic Water System	Back-up water supply (2 feeds, either	24	Medium		4											24			
Water	Domestic Water System	Delivery, storage, distribution system	2	Low		2														
Water	Domestic Water System	Drinking water supply	30	Medium		5											30			
Water	Domestic Water System	Plumbing fixture supply (toilets,	30	Medium		6											30			
Water	Domestic Water System	Process water supply (central sterile,	24	Medium		4											24			
Water	Domestic Water System	Quality	0	Low																
Water	Domestic Water System	Quantity	24	Medium													24			
Water	Domestic Water System	RO Water (for labs, renal, MDRD) - on	30	Medium		5											30			
Water	Domestic Water System	Water treatment/quality (assuming	4	Low		4														
Water	HVAC Systems	Cooling tower makeup water	0	Low																
Water	HVAC Systems	Thermal plant make-up water	0	Low																
Water	Storm Water Management System	Ground level storm water drainage	0	Low																
Water	Storm Water Management System	Permeable cover, bioswales	0	Low																

Appendix F: Project Team Members

Appendix F - Project Team Members

TABLE F.1 PROJECT CONSULTANT MEMBERS		
Role	Member	Organization
Project Manager	Harvey Goodman, P.Eng.	RDH Building Science Inc.
Project Manager	Robert Lepage, MASc., P.Eng.	RDH Building Science Inc.
Mechanical System Lead	Douglas Spratt, MSc, P.Eng.	Prism Engineering Ltd.
Electrical System Lead	Casey Gaetz, LC	Prism Engineering Ltd.
Structural System Lead	Robert Lepage, MASc, P.Eng.	RDH Building Science Inc.
Enclosure System Lead	Robert Lepage, MASc, P.Eng.	RDH Building Science Inc.
Water System Lead	Christy Love, P.Eng.	RDH Building Science Inc.
Civil System Lead	Darryl Tunnicliffe, P.Eng.	McElhanney Consulting Services Ltd.
PIEVC Advisor	Greg Allen, BASc., P.Eng.	Rivercourt Engineering
Climate Change Advisor	Deborah Harford	Adaptation to Climate Change team, Simon Fraser University

TABLE F.2 ISLAND HEALTH PROJECT MANAGER		
Role	Member	Organization
Island Health Project Manager	Joe Ciarniello, MEng, P.Eng., CEM	Island Health

TABLE F.3 PROJECT ADVISORY COMMITTEE MEMBERS		
Member	Title	Organization
Robert Bradley	Energy Conservation Manager	Fraser Health Authority
Deanna Fourt, AScT	Director of Energy Efficiency and Conservation	Island Health
David Lapp, FEC, P.Eng	Practice Lead, Engineering and Public Policy	Engineers Canada
Jim Latham	Manager of Facilities, Maintenance & Operation	Nanaimo Regional General Hospital, Island Health
Trevor Murdock, MSc	Regional Climate Impacts, Lead	Pacific Climate Impacts Consortium
Dave Neufeld	Mechanical Engineer	Island Health
Ting Pan, MSc	Sustainability Coordinator	Island Health
Dragana Perisic	Director, Capital Policy and Planning	BC Ministry of Health
Harshan Radhakrishnan, MASc, P.Eng.	Practice Advisor	Engineers & Geoscientists BC
Gregory Richardson, MCIP, RPP	Policy Analyst	Health Canada

TABLE F.3 PROJECT ADVISORY COMMITTEE MEMBERS		
Member	Title	Organization
Gerry Underhill	Architect	Island Health
Linda Varangu, M.Eng.	Executive Director	Canadian Coalition for Green Health Care
Johanna Wolf, PhD	Senior Policy Analyst, Climate Risk Management	BC Ministry of Environment
Angie Woo, MSc	Climate Resiliency & Adaptation, Lead	Fraser Health Authority

TABLE F.4 OTHER PROJECT PARTICIPANTS	
Name	Organization
Dean Claughton	Island Health
Marci Ekland	Island Health
Ken Hewer	Island Health
Gary Kaczynski	Island Health
Sheena MacKay	Island Health
James Mckenzie	Island Health
Bryan Quaife	Island Health
Tony Steel	Island Health
Trevor Wagenaar	Island Health
Calvin Winquist	Island Health
Mike Wright	Island Health
Andrew Pape-Salmon	Building and Safety Standards Branch
Edward Nichol	Simon Fraser University
Ainaz Bozorgzadeh	Prism Engineering
Stefanie Jones	Prism Engineering
Stephen Kooiman	Prism Engineering
Trevor Nightingale	National Research Council
Peter Fitch	RDH Building Science Inc.
Kelly Haines	RDH Building Science Inc.
Kyle Jang	RDH Building Science Inc.
Steve Kemp	RDH Building Science Inc.
Hannah Kim	RDH Building Science Inc.